CHEM. LIBRARY
FEB 21 1922
CHEMICAL LIBRARY
FEB 21 1922

Transactions of American Society for Steel Treating

Published Monthly | Cleveland, February, 1922 | Ten Dollars a Year

Vol. II | *Entered as second-class matter Feb. 7, 1921 at the post-office at Cleveland, Ohio, under the Act of March 3, 1879.* | No. 5

SPECIAL FEATURES

Cold Headed Bolts—Their Metallography and Heat Treatment — *V. E. Hillman*

New Development on the Influence of Mass in Heat Treatment — *E. J. Janitzky*

Calite—A New Heat Resisting Alloy — *G. R. Brophy*

Magnetic Testing of Small Case Hardened Chain — *A. V. de Forest*

Perfecting a Drop Forging — *J. H. G. Williams*

Comments on E. J. Janitzky's Paper — *Sir Robert Hadfield*

Influence of the Heating Medium on the Structural Changes in Steel — *A. E. Bellis*

Cyanamide in Liquid Case Hardening — *P. W. Shimer and E. B. Shimer*

Tensile Properties of Some Structural Alloy Steels — *H. J. French*

A University Course in Metallurgical Engineering — *W. P. Wood*

Buying Steel on Closer Carbon Limits — *E. W. Pierce*

A Successful Bonus System Applied to Heat Treating — *A. A. Blue*

The Heat Treatment of Steel Castings — *Walter H. White*

Reconnoitering in Automotive Circles — *V. A. Crosby*

Table of Contents, Page 27

Copyright 1922, American Society for Steel Treating

4600 Prospect Avenue

VANADIUM

(The Master Alloy)

STEEL

UNSURPASSED

Forgeability
Ease of Heat Treatment
Machineability
Strength
Toughness
Resistance to Shock and Fatigue

Vanadium Corporation of America

120 Broadway **New York**

Chicago
208 South LaSalle St.

Detroit
849 Book Building

TRANSACTIONS

of the

American Society for Steel Treating

Vol. II Cleveland, February, 1922 No. 5

PAPERS FOR NEW YORK MEETING ARE PREPRINTED

ON FRIDAY, March 3, the Society will hold its first sectional meeting in New York. Special effort has been made to make this meeting a success, the New York Chapter having rendered much assistance in the arrangement of the final details. Hotel McAlpin, Broadway and Thirty-fourth street, will be the headquarters for both registration and meetings. It is urged that members expecting to attend the meeting make hotel reservations without delay. Within the next few days all members of the Society will be advised by mail as to the complete program for the meeting.

As far as the technical sessions are concerned, some six papers will be presented. Five of these papers are preprinted and appear on pages 369 to 395 of this issue of TRANSACTIONS. This is the first time that papers to be presented at the Society's meetings have been printed in advance, although the advantage of so doing has been recognized. It now will be possible for members to become familiar with the papers before they are presented by the author, thus the discussion which is provoked should prove of great value. It is to be hoped that more discussion will be forthcoming and that a greater number will enter into it. As a matter of fact, greater benefit frequently is derived from discussion of a paper than from the paper itself. The New York meeting has every indication of producing gratifying results.

ANNUAL CONVENTION DATE IS CHANGED

THE 1922 Convention and Exhibtion of the American Society for Steel Treating was originally announced for the week of Sept. 25 to 30 at Detroit, but it has become necessary to postpone the date another week so that the convention will be held during the first week of the following month from Oct. 2 to 7.

Definite arrangements have been made whereby the Society will have the use of the exhibition hall in the General Motors Office building, shown in the accompanying illustration. This exposition hall will give the Society one of the best locations it has ever had. The room is 60 x 500 feet and is well supplied with electrical and gas connections.

The meetings for presentation of papers will be held in the same building as well as the entertainment features and the very best of accommodations will be available.

The Detroit Chapter has appointed its Convention committee of which "Billy" Woodside of the Studebaker Corp. is general chairman, and it is

planned to maintain the reputation established by the local chapters of the cities in which previous conventions have been held.

Floor plans and contracts for space will be prepared and sent out within the next few weeks.

THE RIGHT MAN FOR THE RIGHT JOB

RESULTS that have been obtained by the employment bureau of the Federated American Engineering Societies of New York City in securing positions for unemployed engineers during this industrial depression must be most gratifying to those directly interested and intimately associated with this activity. The plan of operations consisted, briefly, in a committee of unemployed engineers, making a systematic canvass of employers and consulting engineers. The positions, which were discovered in this manner, if not desired by the canvasser, were turned in to the employment office, to be filled from the list of applicants whose names were on file. The greatest benefit probably has been derived not from the mere number of positions filled, but by bringing the employer's attention to the service that this employment bureau is capable of rendering them in filling engineering positions of all grades. The result of this campaign has been at least two-fold; that

General Motors Building, Detroit, Where 1922 Annual Convention and Exhibition Will Be Held

of obtaining positions for some who were out of employment and that of establishing a more tangible connection with employers.

The Employment Service Bureau of the American Society for Steel Treating is a service bureau for the use of all members of the Society. It has the welfare of its members at heart. It has functioned well in the past and must function very much better in the future to be of maximum service to all. The only way in which it can function better than it has is by greater support and co-operation of both employer and employe in making use of services it can render. There are probably more men out of positions at this time than ever before and it is the work of the Service Bureau to bring the men and the positions together.

The ways and means of accomplishing this purpose necessarily will be different from those used by the New York societies due to the fact that our membership is more scattered and cannot be as easily canvassed by personal calls. Our TRANSACTIONS reach approximately 3500 individual members each month and through the columns which are devoted to the Service Bureau, both employer and employe are reached. The results obtained through the activity of this bureau are indeed very gratifying, but it is felt that the full benefit of this service is not being used by enough of our members. In spite of the fact that there has been a marked falling off in business, there has likewise been a large turnover of personnel in many organizations. Although there are many men out of employment these days, many of whom are capable men who have been unfortunate in being members of organizations which have been disbanded, the employer is still confronted with much the same problem he has always been confronted with when he is in need of a new man to fill a vacancy or new position; that of finding the right man at the time when he wants him.

It is our earnest desire that our employment service bureau be an outstanding feature of the Society's activities and it is urged that a much more extended use be made of this department. It is regretted that the postal regulations demand that a small minimum fee be charged for all advertising insertions which are made but these advertisements are not at all a part of the requirements in making use of this service. An applicant does not need to run an advertisement to get the full benefit of this service. All that he needs to do is to communicate with the Society's main office and state his desires and they will be given full and prompt attention. The employer especially is urged to make known his needs so that the Society can aid both him and applicants for positions.

Our motto—*"ALL FOR EACH AND EACH FOR ALL"*—is just as truly our motto today as it was the day it was selected. Can we not all play our full part in making this motto something more than a motto and really be of service to our fellow workers?

RESEARCH VERSUS INVESTIGATION

RESEARCH; a systematic study of certain phenomena by the experimental method.

Investigation; the act of inquiring into systematically.

These two terms are used almost synonymously in referring to any piece of study which may or may not be dealing with facts already established by previous study. There appears to be a decided distinction between investigation and research. An investigation may be a simple inquiry into the causes for a certain result which has been observed. Such an

inquiry may cover perfectly well known facts which were evidently temporarily obscured by other outstanding features of the case. A research as we wish to look upon the meaning of the word is a more profound systematic study of phenomena, the causes for which we are not fully aware.

For several years the Board of Directors has given considerable thought to a proposed research laboratory to be maintained by the Society and to be governed by the Research Committee, under whose supervision would come the problems for study. The cost of such an undertaking would have to be defrayed by the Society or by special subscriptions or endowments.

It is well known that the costs involved in establishing a fully equipped research laboratory such as would be required to study metallurgical problems, would involve upward of $100,000 initial investment. To equip a small chemical and physical laboratory, such as one frequently finds in industrial establishments for routine testing and checking of raw materials, and expenditure of $20,000 to $25,000 usually is involved. Such a laboratory, while suitable for the purpose intended and for certain simple investigations, would be entirely unsuited for conducting real research studies.

If our Society undertakes to proceed with problems of research, it must not be handicapped or hampered with insufficient or improper equipment with which to carry out such work.

The Society feels highly complimented and honored in having been tendered several very cordial invitations to make free use of the facilities and council offered by several nationally known and recognized institutions, which are especially and fully equipped to conduct metallurgical researches. Undoubtedly the Board of Directors will consider the acceptance of one or more of these invitations.

Such a research department, of course, would be for the use and benefit of the members of the Society and the problems for study will, in many cases come from suggestions from the membership at large. The problems which will undoubtedly be selected, will be problems which are vital to certain lines of endeavor and which are knotty and troublesome factors entering into the production of certain structural parts, tools, dies, etc. It would not be the purpose of this research section to investigate the cause of failure of parts or tools, etc., of any individual manufacturer, which failures are only intermittent and probably due to any one of a dozen causes, most of which are traceable to carelessness on the part of some workman. Such problems are for routine laboratories and not for research studies, unless they are chronic difficulties experienced by many manufacturers in the same line of work. The distinction which we wish to bring out, is that the Society does not intend to conduct a department which in any way will interfere with the activities of commercial testing laboratories or consulting engineers, but it does aim to aid in the advancement of the metallurgical realm and especially that of the heat treatment of metals.

ARRANGEMENTS MADE TO BIND TRANSACTIONS

MEMBERS of the Society who may wish to have their TRANSACTIONS bound are directed to page 8 in the advertising section of this issue where complete information with reference to the same will be found.

There has been a heavy demand for the March issue, Volume 1, No. 6 1921 of the TRANSACTIONS, and any member having a copy he wishes to dispose of should forward the same to the National Office where they will be paid for at the rate of 75c each.

COLD HEADED BOLTS—THEIR METALLOGRAPHY AND HEAT TREATMENT

By V. E. Hillman

METALLURGICAL features involved in the fabrication of cold headed bolts will be dealt with in this paper. The history of the art reverts back to the early Egyptians who used hand formed rivets in the construction of their various types of implements. The first commercial development of the process took place in England in 1760, when two brothers John and William Wyatt constructed a machine for heading wood screws. Thirty-four years later, a "cold header" was developed and patented in America. The cold heading industry has made rapid strides during the past decade and today, enormous quantities of bolts ½-inch and smaller are being made by this process. These remarks apply particularly to stove and tap bolts, machine screws, cultivator bolts, wood screws, and sink bolts. Metallurgists contributed their share of thoughtful attention to the advancement of the art by developing a steel that would sustain the duty imposed upon it.

The term, "cold work", implies that energy is expended on the metal when its temperature is below the critical range. The microstructure of the metal prior to the application of cold work consists of an aggregate of crystalline grains or cells, each grain being a structural unit. It may suffer rupture or deformation; it may be enlarged, elongated, stressed, or restored to its normal size and shape. When the metal is subjected to mechanical pressure, the crystals are crushed and intimately mixed. Cold work has an embrittling effect upon the metal and the grains which were originally equiaxed are elongated, assuming a ropy appearance resembling fiber. In brief the grains lose their original identity.

This change in microstructure alters the physical properties of the

A paper to be presented at the New York Sectional Meeting, March 3. The author, V. E. Hillman, is metallurgist, Crompton & Knowles Loom Works, Worcester, Mass.

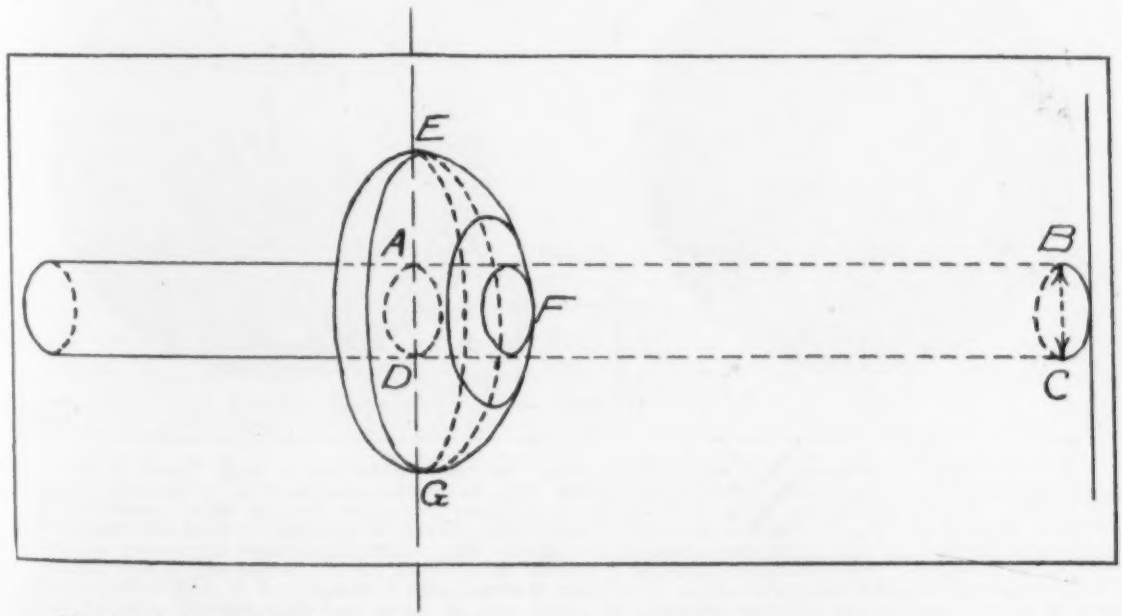


Fig. 1—Sketch showing the maximum amount of stock which may be upset into the head of a bolt without danger from "cold shuts"

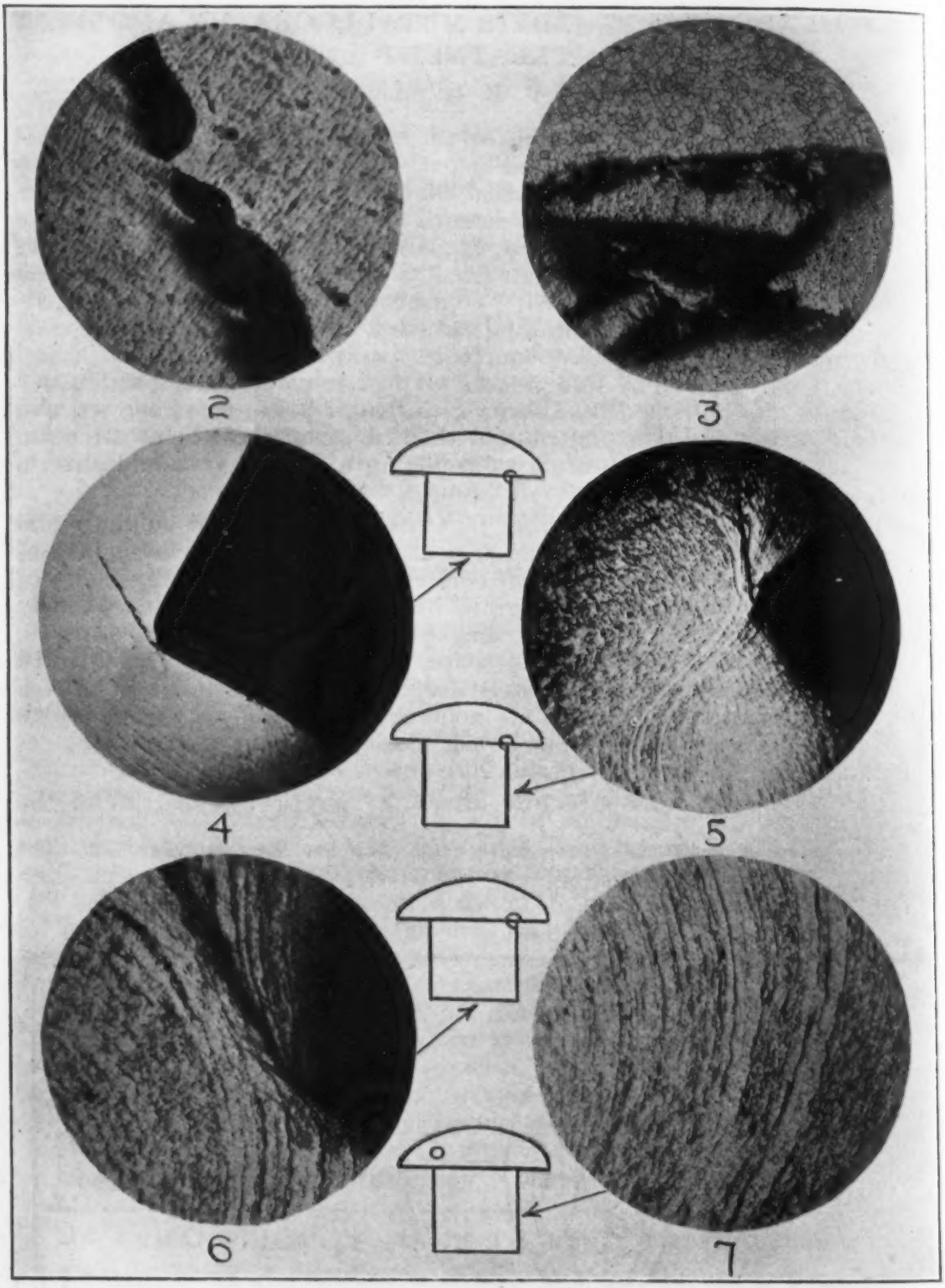


Fig. 2—Unetched specimen of a "cold shut," caused by upsetting too much stock. Note the flow of metal at one point and the isthmus. Etched and X 100. Fig. 3—Another example of a "cold shut." Etched and X 100. Observe strained condition of the metal in the center at extreme left and right. Imperfect flow of metal pronounced. Fig. 4—Manner in which a crack may develop at junction of head and shank, the sharp angle acting as a seat of rupture. Etched and X 45. Fig. 5—Highly strained appearance of grains in vicinity of rupture. Note elongated ferrite band resembling a French curve. Etched and X 45. Fig. 6—Photomicrograph showing banded structure of strained ferrite grains. Etched and X 100. Observe that lines of deformation assume different direction on either side of cavity and that severely strained areas gradually increase as crevice is approached. Fig. 7—Elongation of ferrite and pearlite grains, showing the flattened crystals incident to forming the head. Etched and X 100

steel. The elastic limit, tensile strength, specific gravity, and hardness are increased; whereas, the percentage elongation and reduction of area are diminished. There is a limit to the amount of cold work which a piece of steel will sustain. Therefore, the cold working of the metal must be interrupted from time to time to relieve the internal stresses which have been developed. In other words, if the strained steel be heated to above its critical range, for 15 minutes at 1650 degrees Fahr. and quenched, the elongated grain fibers will be effaced and renewed toughness will be conferred on the metal. The restoration of the ferrite and pearlite grains will permit the application of additional cold work thus cold headed bolt manufacturers usually resort to this thermal treatment.

A lower annealing temperature, 1150 degrees Fahr. for one hour, will also suffice to remove partially at least the embrittling effect of cold work. It should be borne in mind, however, that only the strained ferrite grains are influenced by the lower annealing temperature. The pearlite particles remain in their distorted state. Annealing below the critical range has a dual advantage, namely; the operation is less expensive and the scale nuisance is abated. A comparison of the two heat treatments indicates that the higher annealing temperature produces maximum softness, although the difference in the Brinell values is not appreciable. Certain low annealing temperatures will cause crystallization if the grains have not been sufficiently strained. When the metal has suffered only a slight amount of distortion, an annealing temperature between 1280 and 1380 degrees Fahr. should be avoided, lest a coarse structure may result. In rivets, for instance, where merely a small volume of stock has been upset, it is mandatory to anneal below 1280 or above 1380 degrees Fahr. The above law does not apply to grains that have been subjected to an inordinate amount of cold work, because the distortion is sufficient to render the danger range, 1280-1380 degrees Fahr., inoperative. Light cold work, however, with an anneal between 1280 and 1380 degrees Fahr., will produce a fiery, coarse, crystalline structure. Consequently, crystallization is produced by annealing a critically strained bolt within a certain temperature range. The foregoing remarks apply particularly to steel of the following analysis: Carbon 0.10 0.20, manganese 0.30 0.40, sulphur 0.05, and phosphorus 0.025 per cent.

Soft basic steel is well adapted for cold heading process. The carbon content in the metal, however, should be regulated carefully. It is a well recognized fact that if an attempt be made to upset a piece of high carbon stock, the steel will simply bend over; whereas, material of the proper analysis, 0.10-0.20 per cent carbon, will flow readily into a compact mass. It is necessary to regulate the phosphorus content in steel which is to be subjected to the cold heating operation. The use of basic stock, however, implies that the percentage of phosphorus of necessity will be negligible.

There is a limit to the volume of metal that can be fabricated into the head of a bolt. The maximum length of stock which can be formed into the head is equivalent to seven times the diameter of the rod which is being upset. That is to say, if the diameter of the rod be ¼-inch then it is possible to crush 1¾ linear inches into the head. These tolerances should be followed if "cold shuts" are to be the exception and not

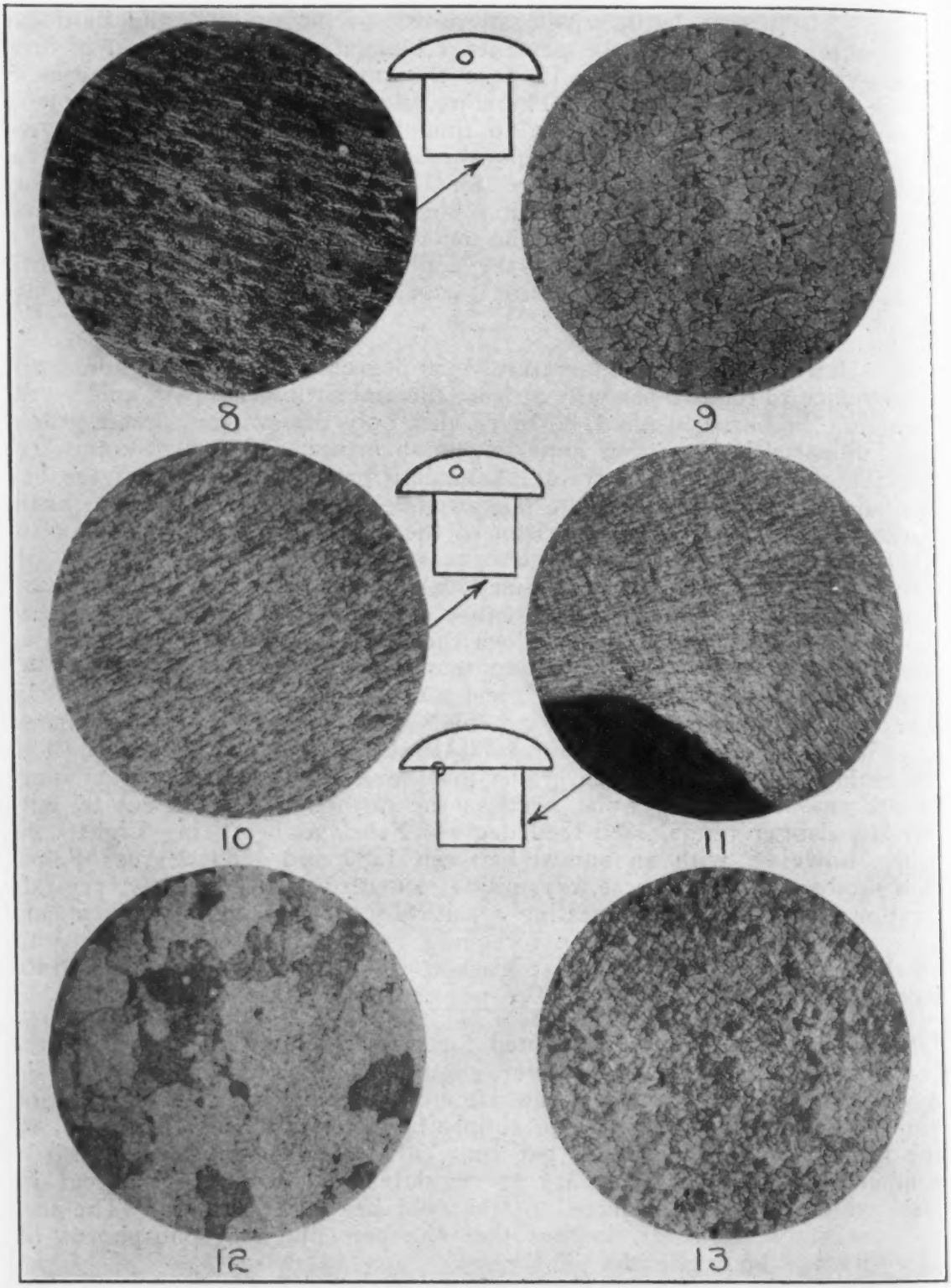


Fig. 8—Another example of effects of cold work, the comprehensive force of the heading operation being responsible for this pattern. Etched and X 100. Fig. 9—This photomicrograph illustrates how grains can be restored to original size and shape by heating specimen above critical range. Etched and X 100. Fig. 10—Slightly strained specimen which would become crystallized if annealed between 1280 and 1380 degrees Fahr. Etched and X 100. The grains have suffered but little distortion. Fiber-like appearance of metal just beginning to show. Fig. 11—Transition from normal grain size to highly strained fibers. Etched and X 100. Fig. 12—Enlarged grain structure produced by annealing a critically strained specimen at 1300-1350 degrees Fahr. Observe the grain growth. Etched and X 100. Fig. 13—Another region from the specimen shown in Fig. 12. Although bolt was annealed in danger zone, a fine grain growth resulted. Etched and X 50

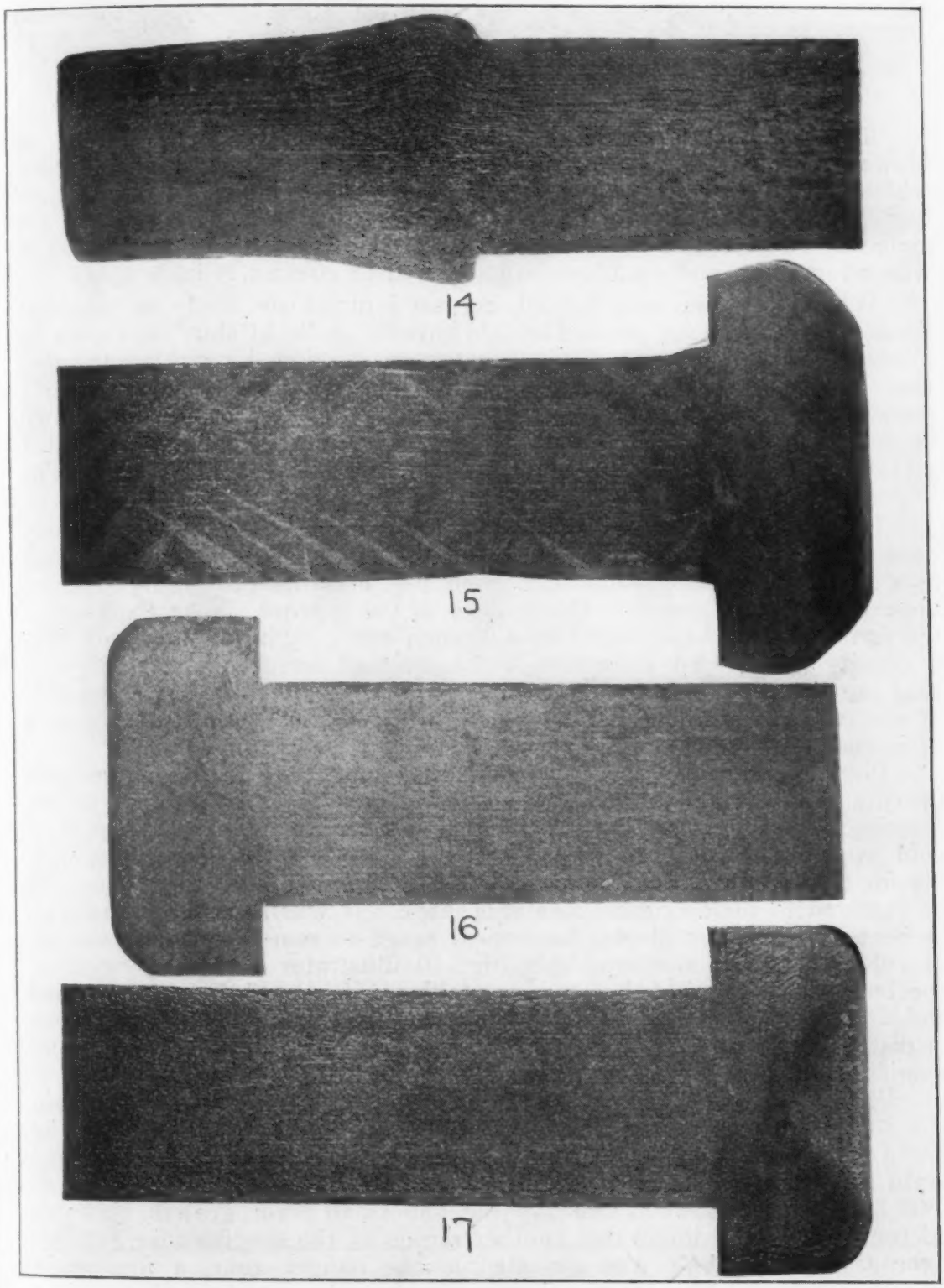


Fig. 14—Macroscopic etching of a bolt after first upset, the strained grain fibers being clearly discernible. Etched and X 3. Contour of strain lines indicates flow of metal. Maximum deformation took place at outer edge of specimen, whereas intensity of distortion increased toward center. Arc at junction of head and shank shows line of demarkation between strained and unstrained areas. Fig. 15—Macroscopic etching after the second upset. Etched and X 3. Greatest strain is in center of head, light areas indicating unstrained metal. The lance-like streaks are caused by polishing. Fig. 16—Another example of the strained condition in the head. Etched and X 3. Area bounded by arcs suffered maximum distortion. The strained fibers resemble a whirlpool. Fig. 17—Same remarks for Fig. 16 apply to this illustration. Etched and X 3

the rule. As shown by Fig. 1, maximum upset limits may be expressed as follows:

$$\text{Volume } ABCD = \text{Volume } EFG$$
$$AB = 7\ BC$$

The reliability of a cold headed bolt is dependent upon the number of blows it received during the fabrication process. The limit of stock which can be compressed into the head by a single blow is two and one-half times the diameter of the rod. Cold headed bolts of commerce are generally subjected to two or three blows. However, there are instances, where four, five, and six blows are required to effect a reliable upset.

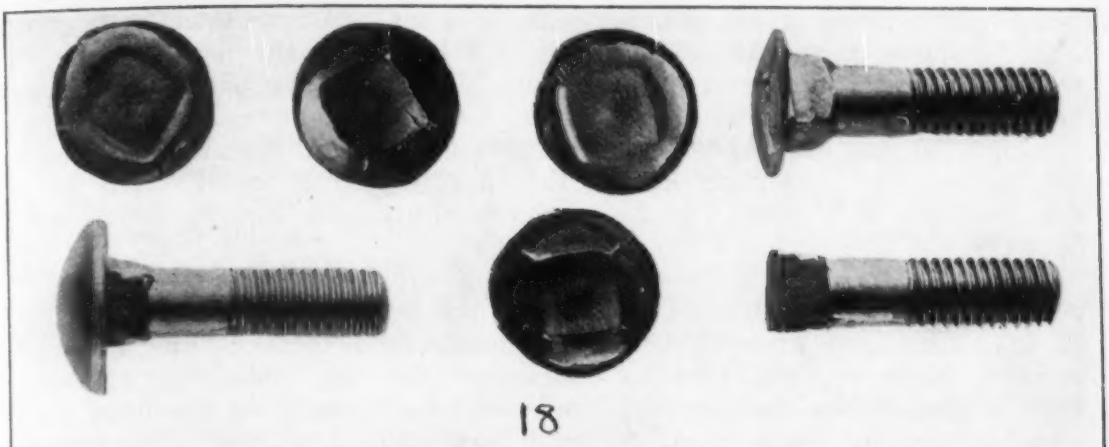
When bolts are cold headed, certain injuries are likely to manifest themselves during the process of fabrication. A "cold shut" is shown in photomicrograph Fig. 2. This defect was occasioned by attempting to upset too much stock. The flow of the metal at one point is clearly shown. Note the isthmus. Another instance of a "cold shut" is shown in the photomicrograph of Fig. 3. Observe the strained condition of the metal in the center of the picture at the extreme left and right. The imperfect flow of the metal is very pronounced.

Photomicrograph Fig. 4 illustrates the manner in which a crack may develop at the junction of the head and the shank. The sharp angle acts as a seat of rupture. Photomicrograph Fig. 5 shows the highly strained appearance of the grains in the vicinity of the rupture. Note the elongated ferrite band which resembles a French curve. Photomicrograph Fig. 6 depicts the banded structure of the strained ferrite grains. Observe that the lines of deformation assume a different direction on either side of the cavity. Moreover, the severely strained areas gradually increase in intensity as the crevice is approached.

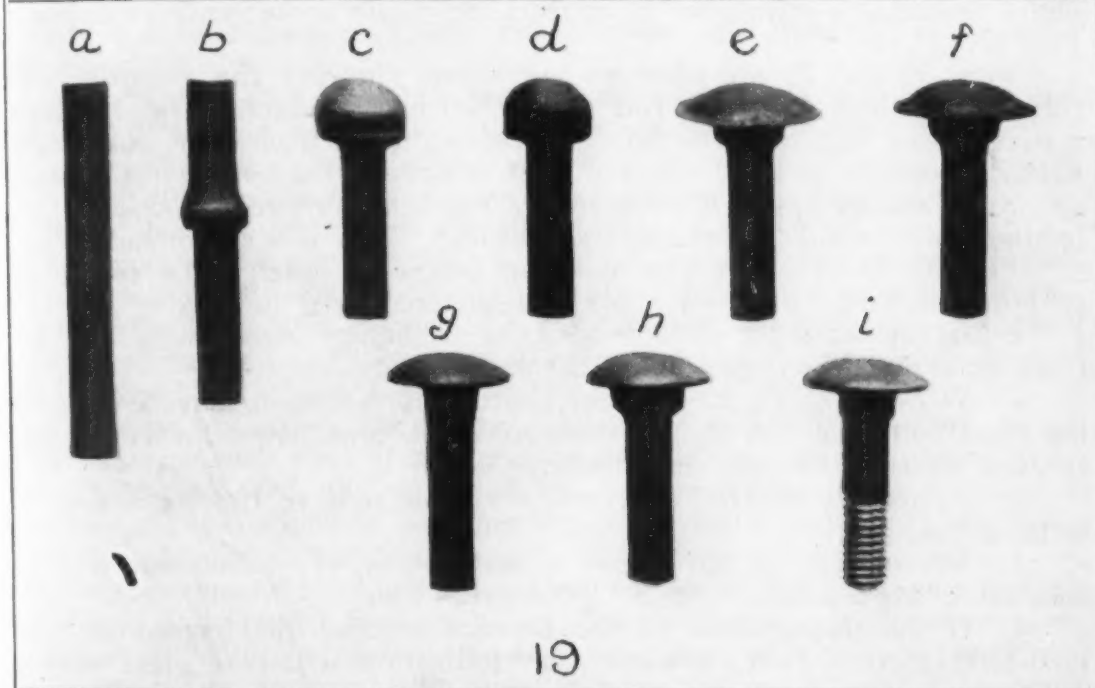
Photomicrograph Fig. 7 portrays the elongation of the ferrite and pearlite grains. This print shows the flattened crystals incident to the forming of the head. Fig. 8 is another representation of the effects of cold work. The compressive force of the heading operation is responsible for this pattern. Photomicrograph Fig. 9 shows how the grains can be restored to their original size and shape. It was necessary, however, to heat the specimen above the critical range to remove the last vestige of cold work. Photomicrograph Fig. 10 illustrates a slightly strained specimen which would become crystallized if annealed between 1280 and 1380 degrees Fahr. The grains have suffered a very small amount of distortion. The fiber-like appearance of the metal is just beginning to manifest itself.

Photomicrograph Fig. 11 shows a transition from the normal grain size to the highly strained fibers. Strained and unstrained areas may be found in the same bolt. Photomicrograph Fig. 12 shows an enlarged grain structure produced by annealing a critically strained specimen at 1300-1350 degrees Fahr. Observe the abnormal grain growth. Photomicrograph Fig. 13 illustrates another region of the specimen in Fig. 12. Even though the bolt was annealed in the danger zone, a fine grain growth resulted. The reason therefor is that the metal in the subject area was sufficiently strained to prevent crystallization.

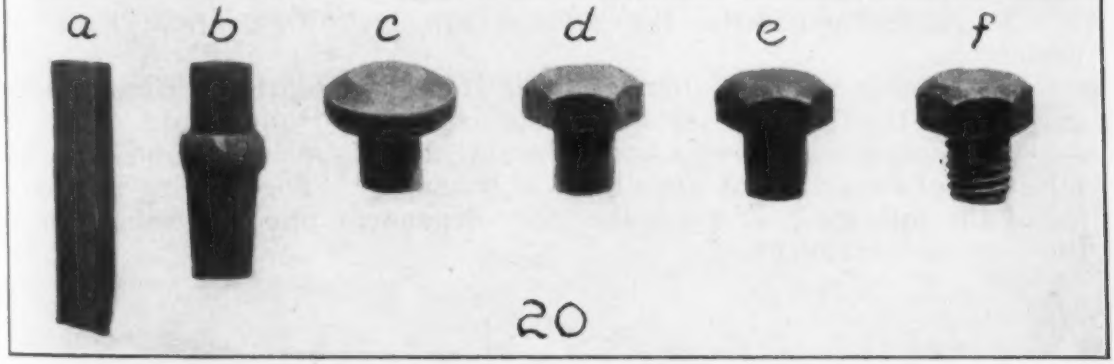
In Fig. 18 is illustrated several exhibits of cold headed bolts which failed in service. The defect may have been occasioned by one or more of the following causes, namely: Omission of heat treatment, excessive quantity of material in the head, carbon segregation, scale, slag inclu-



18



19



20

Fig. 18—Several exhibits of cold headed bolts which failed in service, failure probably being due to omission of heat treatment, excessive material in head, carbon segregation, scale, slag inclusions, ghost lines, or abnormal hardness in rod prior to cold heading. Fig. 19—Evolution of a round head, square shank bolt, cold upset, made from basic cold drawn wire. *A* piece of stock used, *b* first upset, *c* second upset, *d* annealing, *e* reheading or pressing cold, *f* heat treating, *g* trimming, *h* pointing, and *i* threading with a cut thread. Fig. 20—Evolution of a hexagon head tap bolt, cold upset, made from basic cold drawn wire. *A* piece of stock used, *b* first upset, *c* second upset, *d* trimming, *e* annealing and heat treating, *f* threading with a rolled thread

sions, ghost lines, or abnormal hardness in the rod prior to cold heading. Fig. 14 shows a microscopic etching of a bolt after the first upset. The strained grain fibers are clearly discernible. The flow of the metal may be observed by following the contour of the strain lines. The maximum deformation has taken place at the outer edge of the specimen; whereas, the intensity of distortion has decreased toward the center. The arc at the junction of the head and the shank shows the line of demarkation between the strained and unstrained areas.

Fig. 15 shows a microscopic etching after the second upset. The position of greatest strain is shown in the center of the head. That is to say, the light areas indicate the unstrained metal. The lance-like streaks, however, are strains occasioned by the polishing operation. Fig. 16 also shows the strained condition of the metal in the head. The area bounded by the arcs has suffered maximum distortion. The strained fibers resemble a whirlpool in appearance. The same remarks apply to Fig. 17.

Figs. 19 and 20 are photographic views showing the evolution of a cold headed bolt from the rod to the finished product. Fig. 19 shows a round head, square shank bolt, cold upset, made from basic cold drawn wire. *a* shows a piece of material used in making the bolt; *b* the first upset; *c* the second upset; *d* annealing; *e* reheading or pressing cold; *f* heat treating; *g* trimming; *h* pointing; *i* threading. This is a cut thread.

Fig. 20 shows a hexagon head tap bolt, cold upset, made from basic cold drawn wire. *a* shows a piece of material used in making the bolt; *b* the first upset; *c* the second upset; *d* trimming; *e* annealing and heat treating; and *f* threading. This is a rolled thread.

CONCLUSIONS. 1. Various degrees of distortion may be found in the same bolt. Certain regions undergo slight deformation, whereas, other sections undergo extreme distortion.

2. Annealing at 1150 degrees Fahr. will remove the weakening effects of cold work.

3. Irrespective of the degree of cold work, crystallization will not take place below 1280 or above 1380 degrees Fahr.

4. If the temperature of the furnace reaches the hazardous zone, 1280-1380 degrees Fahr., however, crystallization will take place only in those areas which have been slightly strained.

5. Annealing above the critical range, 1650 degrees Fahr., is preferable.

6. In this range of temperature, 1625-1675 degrees Fahr., and regardless of the degree of strain, crystallization will not result.

The successful manufacture of cold headed bolts demands the application of fundamental metallurgical principles. The quality and service of the finished product is therefore dependent upon an adherence to the laws of metallurgy.

NEW DEVELOPMENT ON THE INFLUENCE OF MASS IN HEAT TREATMENT

By E. J. Janitzky

IN THE paper dealing with the influence of mass in heat treatment, read at the Indianapolis convention of the American Society for Steel Treating, and published on page 55 of the October, 1921 issue of TRANSACTIONS, the author confined himself to data taken on a 0.45 per cent carbon steel, as published by the British Engineering Standards association in their report No. 75, dated October, 1920. In this paper it was shown that the hardness-mass formula is

$$B = \frac{n\,C}{(D-d)} + b$$

in which B is the Brinell hardness of any section.
n is a factor which is constant for each steel of a particular analysis.
C is 14.125, which represents the product of the diameter and surface per pound of steel of any round section.
D is the diameter of the section, the hardness of which is desired.
d corresponds to the vertical asymptote of the curve.
b is the normalized Brinell hardness of the steel.

The object of the present paper is to show that the same general formula that was used for plain carbon steel is applicable to structural alloy steels; also that this formula holds good for the "midway" Brinells, that is, Brinell hardnesses taken half way between the centers and outsides of rounds on their cross sections.

In his previous paper, the author pointed out that n is a factor which is constant for each steel of a particular analysis, and which appears to be, for plain carbon steel, the square of the hardening capacity of the steel in question. As the variable d is a function of the factor n, it is obvious that n is the salient point of the formula.

From experiments soon to be described on two nickel steels, one chrome-nickel steel and from data given by the British Engineering Standards association on a 5 per cent nickel case hardening steel, it became apparent that the factor n for structural alloy steel is twice the square of the hardening capacity, or more generally expressed, a multiple of the square of the hardening capacity, thus, $n=2\left(\frac{B_M}{b}\right)^2$, in which

B_M is the maximum Brinell hardness which can be developed in the steel.
b is the normalized Brinell hardness of that steel.

Thus, for a 0.32 per cent carbon, 3.25 per cent nickel steel,

$$n=2\left(\frac{532}{196}\right)^2=14.73$$

A paper to be presented at the New York Sectional Meeting, March 3. The author, E. J. Janitzky, is metallurgical engineer, Illinois Steel Co., South Chicago, Ill. In this paper the author has answered the criticisms of Sir Robert Hadfield on his previous paper. These criticisms appear on page 396 of this issue of TRANSACTIONS.

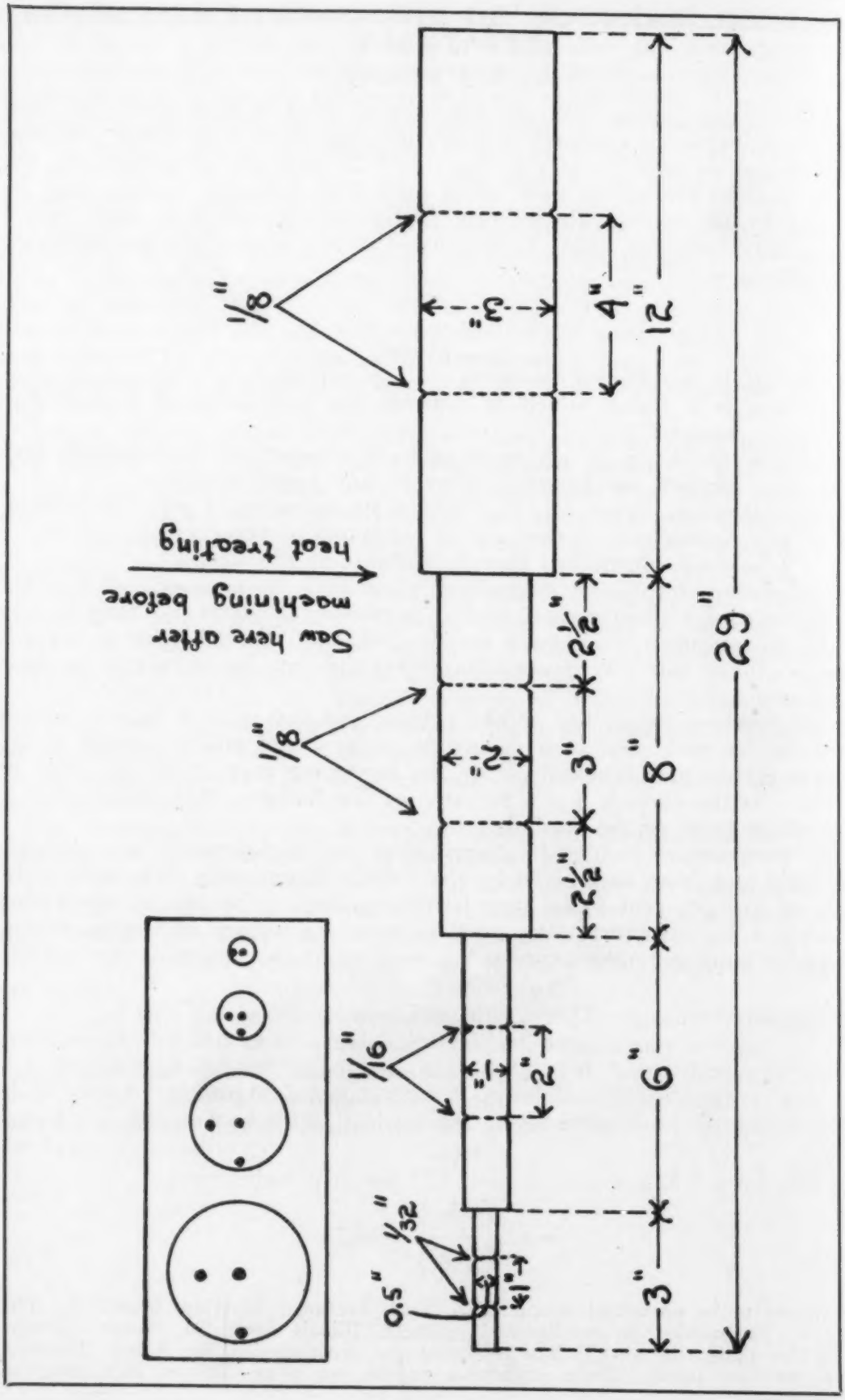


Fig. 1—Standard test specimen for determining the influence of mass in heat treatment. In upper left-hand corner are shown cross sections of the four diameters, indicating the points at which Brinell measurements were taken

For a 0.42 per cent carbon, 3.15 per cent nickel steel,

$$n=2\left(\frac{600}{217}\right)^2=15.27$$

For a 0.34 per cent carbon, 1.20 per cent nickel, 0.56 per cent chromium steel,

$$n=2\left(\frac{555}{217}\right)^2=13.08$$

For a 0.17 per cent carbon, 5 per cent nickel case hardening steel,

$$n=2\left(\frac{388}{187}\right)^2=8.6$$

The specimen used to make these experiments is shown in Fig. 1. It is composed of four sections, each nicked circumferencially as indicated, so that, at the nicks, the diameters of each of the sections respectively is approximately 0.5, 1.0, 2.0 and 3.0 inches. It is best to cut the specimen into two parts before quenching, as this facilitates handling; cutting should be done at the junction of the 2 and 3-inch sections as shown in Fig. 1. After quenching the test pieces should be broken at the nicks and the fractured surfaces ground Brinell hardness numbers should then be obtained on three places of the ground cross sections, thus, close to the surface (circumferencial), midway and in the center. In a 0.5-inch round there will be little or no variation in hardness between the center and the outside, but it is obvious that as the section grows larger this difference becomes greater. Ordinarily after quenching the 3-inch round can be cut with a saw in which case, of course, it is not necessary to fracture it.

It will be noted in all of the following tables that the hardness of the 0.5-inch section is not calculated. The 0.5-inch section is used only to obtain the maximum hardness which can be developed in the steel. A section of this diameter has been chosen to determine the maximum Brinell hardness because it is the smallest one which can be treated practically and brinelled on the cross section. A smaller section is liable to crack in drastic quenching and does not allow the Brinell hardness of it to be obtained.

When a section of steel is quenched, a section so small that it has on quenching a perfect martensitic structure, the quenching of a smaller section will not give a higher Brinell hardness than that obtained in the section just mentioned. Thus, in alloy steels of the structural type, this largest section at which the maximum Brinell hardness can be obtained is on a section having a diameter somewhere between 0.5 and 1.0 inch. Therefore it is not to be expected that the theoretical curve will pass through the point corresponding to the actual Brinell hardness obtained for 0.5 inch.

The following tables give actual and calculated data of the center and midway Brinell hardness of sections whose diameters are shown:

(1). 3.5 *per cent nickel steel quenched in water at* 1450 *degrees Fahr.*

The composition of the steel was carbon 0.32, manganese 0.56 and nickel 3.25 per cent.

B_M=532, b=196, thus

$$n=2\left(\frac{B_M}{b}\right)^2=14.73$$

Fig. 1—Standard test specimen for determining the influence of mass in heat treatment. In upper left-hand corner are shown cross sections of the four diameters, indicating the points at which Brinell measurements were taken.

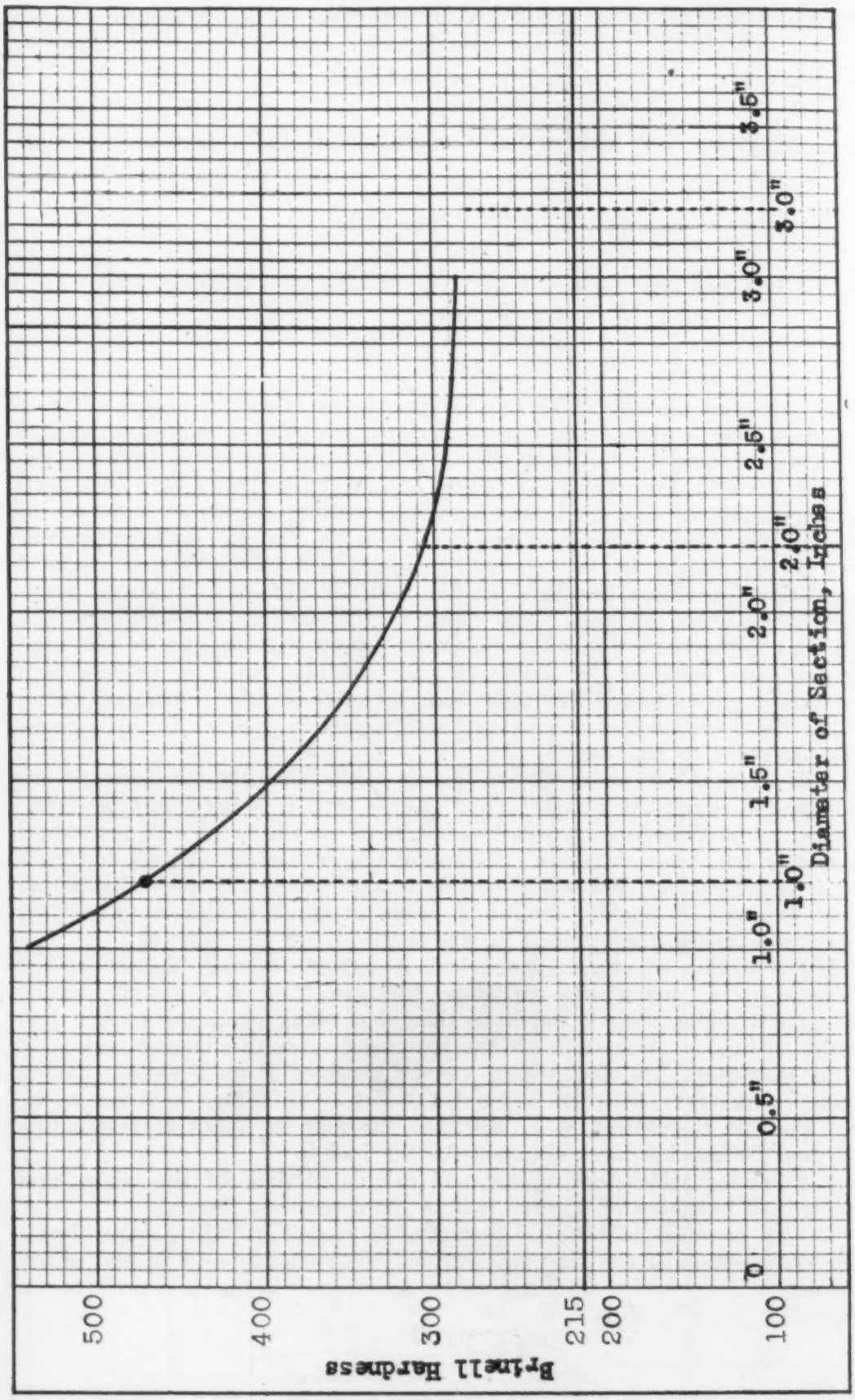


Fig. 2—Water quench curve showing relation of Brinell hardness to diameter of section. After determining the Brinell hardness of a 1-inch section, for example, locate this point on the curve and using the same horizontal scale, read off the Brinell hardness of other sections.

Center Data

$$\text{for 1 inch, } d=1-\frac{(14.125)\quad(14.73)}{430-196}=0.111$$

$$B=\frac{(14.125)\quad(14.73)}{D-0.111}+196$$

The following results were obtained:

Diameter of section inches	Actual Brinell hardness	Calculated Brinell hardness
0.5	532	...
0.73	...	532
1.0	430	430
2.0	302	306
3.0	348	268

Midway Data

$n=14.73$

$$\text{for 1 inch, } d=1-\frac{(14.125)\quad(14.73)}{477-196}=0.260$$

$$B=\frac{(14.125)\quad(14.73)}{D-0.260}+196$$

The following results were obtained::

Diameter of section inches	Actual Brinell hardness	Calculated Brinell hardness
0.5	532	...
0.879	...	532
1.0	477	477
2.0	302	315
3.0	255	272

(2). 3.5 *per cent nickel steel quenched in water at* 1450 *degrees Fahr.* The composition of the steel was carbon 0.42, manganese 0.61 and nickel 3.15 per cent.

$B_M=600$, $b=217$, thus

$$n=2\left[\frac{B_M}{b}\right]^2=15.27$$

Center Data

$$\text{for 1 inch, } d=1-\frac{(14.125)\quad(15.27)}{540-217}=0.332$$

$$B=\frac{(14.125)\quad(15.27)}{D-0.332}+217$$

The following results were obtained:

Diameter of section inches	Actual Brinell hardness	Calculated Brinell hardness
0.5	600	...
0.896	...	600
1.0	540	540
2.0	321	346
3.0	286	298

Fig. 2—Water quench curve showing relation of Brinell hardness to diameter of section. After determining the Brinell hardness of a 1-inch section, for example, locate this point on the curve and using the same horizontal scale, read off the Brinell hardness of other sections

Midway Data

$n=15.27$

$$\text{for 1 inch, } d=1-\frac{(14.125)\quad(15.27)}{555-217}+0.362$$

$$B=\frac{(14.125)\quad(15.27)}{D-0.362}+217$$

The following results were obtained:

Diameter of section inches	Actual Brinell hardness	Calculated Brinell hardness
0.5	600	...
0.925	...	600
1.0	555	555
2.0	340	349
3.0	302	300

(3). *Chrome-nickel steel quenched in water at 1535 degrees Fahr.*

The composition of the steel was carbon 0.34, manganese 0.50, nickel, 1.20 and chromium 0.56 per cent.

$B_M=555$ and $b=217$, thus

$$n=2\left\{\frac{B_M}{b}\right\}^2=13.08$$

Center Data

$$\text{for 1 inch, } d=1-\frac{(14.125)\quad(13.08)}{477-217}=0.289$$

$$B=\frac{(14.125)\quad(13.08)}{D-0.289}+217$$

The following results were obtained:

Diameter of section inches	Actual Brinell hardness	Calculated Brinell hardness
0.5	555	...
0.836	555	555
1.0	477	477
2.0	340	325
3.0	286	285

Midway Data

$n=13.08$

$$\text{for 1 inch, } d=1-\frac{(14.125)\quad(13.08)}{495-217}=0.336$$

$$B=\frac{(14.125)\quad(13.08)}{D-0.336}+217$$

Diameter of section inches	Actual Brinell hardness	Calculated Brinell hardness
0.5	555	...
0.883	...	555
1.0	495	495
2.0	340	328
3.0	302	286

(4) *5 per cent nickel case hardening steel quenched in water at 1580 degrees Fahr. and requenched in water at 1400 degrees Fahr. (From British Report).*

The composition of the steel was carbon 0.17, manganese 0.34 and nickel 5.0 per cent.

$B_M = 388$, $b = 187$, thus

$$n = 2\left(\frac{B_M}{b}\right)^2 = 8.6$$

$$\text{for 1 1/8 inch, } d = 1.125 - \frac{(14.125)\quad(8.6)}{363 - 187} = 0.435$$

$$B = \frac{(14.125)\quad(8.6)}{D - 0.435} + 187$$

The following results were obtained:

Diameter of section inches	Actual Brinell hardness	Calculated Brinell hardness
0.6875	388	...
1.04	...	388
1.125	363	363
1.50	321	300
2.125	277	259

In regard to the formula, it would appear that the Brinell hardness of the steels in the annealed state should be taken for b; however, as we do not deal with sections of indefinite diameter, the value used for b is that of the steel in the normalized condition. It seems to answer the purpose of the formula better for engineering purposes.

It is also obvious that in the case of specimens drawn or quenched in different media, the same procedure should be followed as that in this paper. It is not necessary to calculate the Brinell hardness for sections drawn or quenched in different media, if the water quench curve for that particular steel is at hand. It is only necessary to obtain the Brinell hardness of say, a 1-inch section, fix this point on the water quench curve and using the same scale, read off the Brinell hardnesses of other sections, as shown in Fig. 2.

Attention is called to the fact that the results given in this paper are not averages of a number of tests. They represent a single result of one investigator. If this experiment would be carried out by a number of investigators and the results averaged, still closer checks between the actual and calculated values would be expected.

In concluding the author wishes to state that whereas the first paper was a demonstration of the hyperbolic tendency of the curve of the physical properties of steel sections of the same analysis, this paper endeavors to cover the practical application when one is confronted with the mass problem.

The author wishes hereby to express his appreciation for the assistance rendered by H. Blumberg.

CALITE—A NEW HEAT RESISTING ALLOY

By G. R. Brophy

A FRESHLY cut surface of aluminum, like all metals, will show a bright lustrous surface, but after a very short time in the atmosphere becomes dull. On longer exposure little change takes place in this strongly adherent coating. This is recognized as a protective coating of oxide. Aluminum when alloyed in solid solution with other metals still retains this property of oxidizing readily and lends this property to the alloy.

Advantage of this property was taken a few years ago when calorizing was developed. This process, which has been described many times, consists of coating metals with aluminum at high temperature, actually forming a surface alloy which is highly resistant to oxidation at high temperature and to many forms of corrosion. Calorizing is not suited for work above 1832 degrees Fahr., due to the rapid diffusion of aluminum and the consequent lowering of the surface aluminum content to the point where breakdown under oxidation occurs.

A homogeneous alloy made by melting aluminum with iron naturally will show no such diffusion on subsequent heating, and provided the aluminum content is sufficiently high, the alloy will resist oxidation at temperatures nearly up to its melting point. Unfortunately, on repeated heating and rapid cooling, or uneven heating, these alloys crack badly and no homeopathic doses of any third metal tried—and nearly all were tried—helped this condition. The hot metal when the least moisture touched it acted like hot glass, flying to pieces.

The low expansion of high nickel steels together with the fact that aluminum and nickel form a high melting compound led to investigating the promising ternary alloys of aluminum, nickel and iron. Therefore, keeping aluminum at a minimum and substituting nickel for iron in various percentages, a series of alloys was obtained which showed increasingly good properties. However, when nickel reached 15 per cent the alloy was soft and lost nearly all its resistance to oxidation. This was probably due to the formation of the high melting compound corresponding to the formula NiAl, which, while highly resistant to oxidation itself, robbed the iron of its protection and allowed the iron to scale badly. Further additions of aluminum and nickel in proportions other than that of the above compound finally gave an alloy which was strong; would stand shock, hot or cold; could be quenched repeatedly; and was highly resistant to oxidation. A few further refinements gave the alloy which was finally adapted and which we call calite.

Manganese and silicon above 0.75 per cent both tend to decrease resistance to oxidation, but with care in melting, no trouble is experienced. Carbon increases brittleness and should be kept as low as possible and easily runs under 0.05 per cent. On account of the ease with which SiO_2 slags with aluminum, the melting must be done in a basic furnace. Also the ladle used must have a basic lining.

Basic Heroult type furnaces are used with good success. Steel scrap is first melted down and decarburized; slag is removed and nickel is

---

A paper to be presented at the New York Sectional Meeting, March 3. The author, G. R. Brophy, is metallurgical engineer, industrial furnace department, General Electric Co., Schenectady, N. Y.

added and a new slag made. When all is thoroughly deoxidized, the final slag is removed and scrap calite added to the extent of 25 per cent of the melt and dissolved. The melt is then poured in a preheated ladle containing the required amount of molten aluminum. As this alloying takes place, an exothermic reaction occurs of sufficient intensity to dissolve additional scrap, and up to the present, scrap amounting to 15 per cent of the melt has been dissolved with sufficient residual heat to necessitate holding in the ladle several minutes. The ladle is bottom poured

Annealing boxes made from calite, having run 1500 heat hours without warpage or growth

so that the time of holding allows all oxide to float and nothing but clean metal to be poured.

The metal runs freely, and sections of 3/16-inch have been cast successfully. Any casting which can be made of steel can be made of calite. The shrinkage being the same as steel, the same precautions must be taken.

Calite resists oxidation up to 1300 degrees Cent. (2372 degrees Fahr.) but 1200 degrees Cent. (2200 degrees Fahr.) is recommended for indefinite service. The protective oxide formed is tight and does not snap off even on quenching from high temperatures. Quenching after 100 hours at 1200 degrees Cent., calite lost but 0.03 gram per square centimeter ex-

posed, while the best heat resisting base metal alloy other than calite lost 0.56 gram under the same conditions. The same samples were run at 1300 degrees Cent. for an additional 25 hours. Calite lost 0.003 gram, the other 0.09 gram per square centimeter exposed. From these figures it appears that calite is 20 times as resistant at 1200 degrees Cent. and the only base metal alloy to stand at temperatures higher. At 900 degrees Cent. or ordinary operating temperatures the loss per square centimeter was measured in 1/10 milligram, or for all practical purposes no loss.

Calite is practically noncorrosive. Samples have been polished and run in a spray of saturated sea salt solution at 100 degrees Fahr. for 200 hours and at the end of this time still retained the perfect polish. So called stainless steel will last but a few hours in this test. For fittings exposed to salt atmosphere calite should be excellent.

Twenty-five per cent sulphuric acid dissolves calite rapidly; hydrochloric acid slowly and nitric hardly at all. Forty-eight hours in 25 per cent nitric acid, the metal lost 0.0004 gram per square centimeter exposed. Acetic acid has no effect. Molten carbonates, chlorides, nitrates, cyanides, Pb, Zn, Sn, type metal, sulphur and sulphur vapor do not attack calite. SO_2 gas at 900 degrees Cent. has no attack. Fluxes such as cryolite, borates and silicates attack calite rapidly.

In general, the physical properties are as follows:

Melting point, degrees Fahr	2777
Softening temperature, degrees Fahr	2500
Working temperature, degrees Fahr	2200-2370
Specific gravity	7.03
Weight per cubic inch, pounds	0.25
Brinell hardness, annealed	286
Sclerescope hardness, Annealed	40
Thermal conductivity, per cent of iron	25
Transverse stress, 1-inch square bar, pounds per square inch	4250
Tensile stress, pounds per square inch	36,800

Calite cannot be machined in the cast condition, nor cut with oxy-acetylene. Any change of dimension or finish must be done by grinding. It is more resistant to oxidation at high temperatures and will stand higher temperatures than any base metal alloy tested. Its first cost is low and operating cost lower than other nonoxidizing alloys. Boxes shown in the accompanying illustration have been run for 1500 heat hours and will be seen to be in the best condition. Measurements of these boxes show no warpage or growth. The oxide coating is no heavier now than after the first heat.

MAGNETIC TESTING OF SMALL CASE HARDENED CHAIN

By A. V. de Forest

THE problem of determining the depth of case in carbonized and case hardened work is one in which the customary nondestructive methods of test are difficult or impossible to apply. In some cases, the surface hardness may be estimated with a scleroscope or a file, or under favorable conditions a Brinell test can be made, but in general, none of these tests is satisfactory on this class of material. A magnetic method which has been applied successfully to a particular product therefore may be of some interest.

The product under discussion is small steel chain in various diameters of wire from 0.192 up to ⅜-inch, and in short lengths of from 5 to 15 inches. It is used as the cross member in automobile tire chains, where it is exposed to the wear of hard roads, and to the shock of pounding over car rails and cobble stones. The result is that if the case is too thin it wears out too fast, and if too thick, it breaks even before the soft chain has worn out. Fortunately, there is an intermediate condition from which reasonable service may be expected.

In order to determine this condition for maximum service, a test is needed in which any variable which increases the brittleness of the chain will show itself in the direction of increased depth of case. In the present instance, the magnetic property under observation varies with the quenching temperature and the structure of the chain in the desired manner.

Resistance to wear and the resistance to shock are in general inversely proportional to each other, and the point of maximum usefulness is highly indeterminate. The final test, the mileage run on the road, is so full of accidental variations, that the average of a large number of records must be considered. This has so far prevented a close study of the effect of small changes in structure. If we consider the depth of case as the only variable, and make the chain from the same wire, carbonize at the same temperature in the same compound for different times, and quench all our chains from the same temperature, we obtain magnetic readings proportional to the depth of case. If then a set of these chains, ranging from thin case to thick are taken off after the first to break has worn through it will be found that the wear is very closely proportional to the magnetic reading. This is shown in the picture, and holds true regardless of the weight of car used or the speed and nature of the road. When the chains are run until all are broken and the mileage of each is considered, it is found that in general the low reading and the high reading have given about the same result; and somewhere between the two is the longest lived chain. The softer the road, and the lighter the car, and the slower it is driven, the closer will the best chain come to the high reading, or deep case end of the scale. However, this hard end is the more dangerous, for a chain overhard for the use to which it is put may break in a few miles, while the too soft chain will wear out only after a fair length of travel.

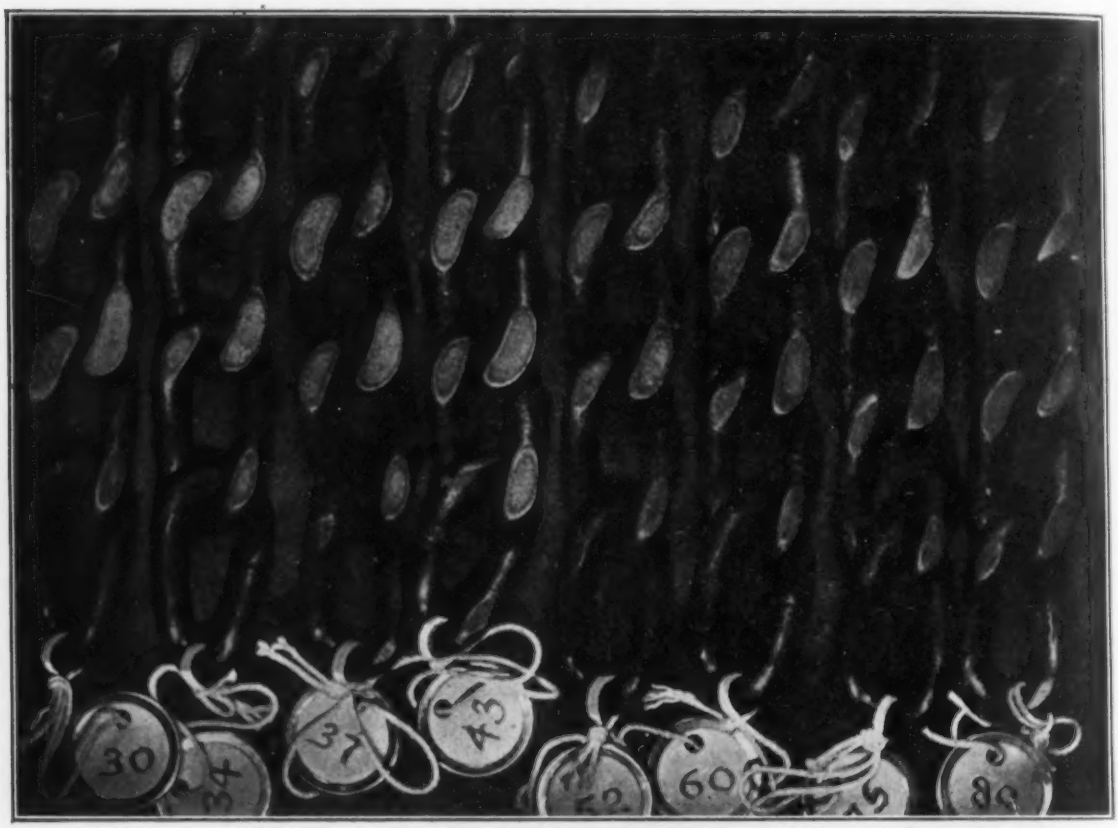
The magnetic test, therefore, is used to determine when the chain is unnecessarily soft or dangerously hard. This latter figure is derived en-

---

A paper to be presented at the New York Sectional Meeting, March 3. The author, A. V. de Forest, is research engineer, American Chain Co., Bridgeport, Conn.

tirely from experience, and is only an estimate to meet the worst conditions. It is not yet practical to make chain to suit the temperament of the driver of each car and the paving of the streets he uses, but some day chains may come like tooth brushes, hard, soft and medium, in properly labeled packages.

Major variables involved are the size of chain; the depth of case; the carbon content of the case and its distribution; the composition of the core; the structure of case and core, as determined by the carbonizing temperature and the heat treatment. The effects of each of these



Specimens of steel automobile skid chain cross links which have been subjected to wearing tests to determine the necessary depth of case

factors on the magnetic result have not as yet been too accurately determined. The following points, however, may be of interest. In the carbonized chain, slowly cooled or normalized, the magnetic reading is closely proportional to the depth of case. Here the core is pretty regular in composition and the carbonizing material the same in each instance. When reheated and quenched the magnetic result is higher the higher the quenching temperature. Furthermore, the magnetic result is higher for a coarse structure as quenched from the pot, than for a finer structure quenched from the same temperature, as is obtained by reheating and requenching. So far the magnetic result has given a pretty close idea of the "brittleness" of the chain whatever that may mean. If now another variable is brought in, the drawing temperature results are not as good. A draw at 450 degrees Fahr. lowers the magnetic reading

more than it affects the life of the chain. At 550 degrees Fahr., the same thing is true. However, in practice, drawing has not so far proved generally advisable so this effect is not a factor in this case.

The magnetic apparatus itself is a simple form of inductance bridge, operating on 60-cycle commercial current. A rather peculiar type of separately excited galvanometer is used as an indicator. A small rheostat and ammeter control the current to operate. In this case about 0.2 amperes at 110 volts are used. Resistance coils control the sensitivity of the instrument, and the deflections can be adjusted to any desired limits. An adjustable resistance is used to balance the galvanometer, and is altered to compensate for different sizes of specimen, or to change the scale of the instrument. Either deflection or null method can be used. The deflection method is ordinarily sufficiently accurate. The magnetizing coil may be of almost any size. The one in question will operate on 1/16-inch wire, chain formed of ⅜-inch wire, or bar stock up to 1¼-inch in diameter. The whole outfit is easily portable and needs no setting up beyond connection to an alternating current lighting circuit.

It has been found that the introduction of a rapid and nondestructive test enabled the testing of a vastly greater number of samples, and a much closer control over the factors affecting the problem. It enables experiments to be conducted intelligently on time of heat, temperature, shape and material of pots or retorts, method of packing, arrangement of furnace, carbonizing mediums, and all the troubles giving rise to the far famed irregularities of case hardened work. Also by giving quantitive results, it allows a better interpretation of service tests on the finished product.

Last but perhaps most important of all, it affords justice to the heat treating force, for careful and intelligent operation can be accurately appreciated and carelessness properly censured. The result is that much greater interest is taken in the quality and uniformity obtainable under routine conditions, and all concerned with this frequently abused department can share the satisfaction of a good job well done.

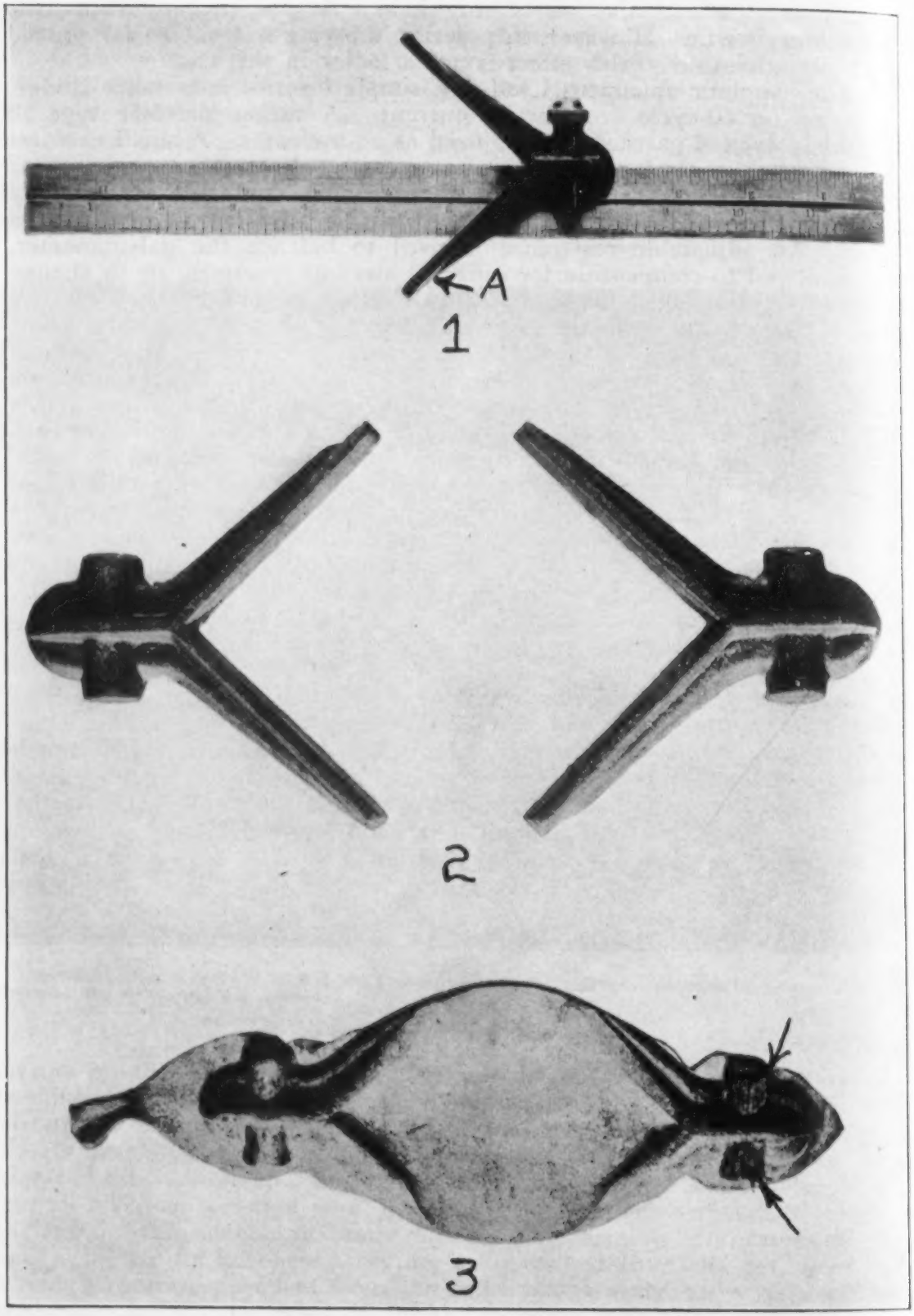


Fig. 1—Photograph of a mechanics square, the portion marked *A* being the part of the forging under discussion. Fig. 2—It has been found desirable to forge the piece double in the die as shown in this illustration. Fig. 3—The third step in the forging operation, the arrows indicating the formation of the boss

PERFECTING A DROP FORGING

J. H. G. Williams

PURCHASERS of drop forgings often are of the opinion that once the dies are made, it is a simple matter to produce sound forgings, and the manufacturer often is of the opinion, privately of course, that the purchaser is unreasonable because he cannot understand how difficult it is to produce sound forgings, once the dies are made.

This disturbing situation is due to a lack of knowledge of the principles underlying the flow of metal in the plastic condition. Scientific research on the subject has not been linked up with the practical applications. The individual die makers have accumulated through experience an empirical knowledge. Every set of drop forge dies is largely the expression of an individual opinion as to the flow of plastic metal. Feeling that it is advantageous sometimes to study the reverse side, the accompanying set of photographs is exhibited to illustrate how metal did not flow in the manner originally planned.

Fig. 1 is a representation of a mechanics square. That part marked *A* is the forging under discussion. The piece is forged double as shown in Fig. 2. There are at least two reasons for arranging to forge double in this manner: The rate of production is increased; and there is less weight of metal involved in the manufacture of two forgings by this arrangement, than would be if the two forgings were made singly. The flash or excess metal surrounding the outside of the forging is trimmed away and excess metal in the center is punched out, which leaves two forgings supposedly ready to machine for use.

At this stage of manufacture, the forgings are inspected, and during the production of the first few dozens, certain defects called "laps" and "cold shuts" were discovered, the causes and elimination of which constitute the basis of this paper. Low carbon steel 1½ x ½-inch is used as raw material. As originally made, the first operation consisted of redistributing the metal from the uniform section shown in Fig. 4, to that shown in Fig. 5. It will be observed in Fig. 5 that there is a mass or bunch of metal at *A* and *B* corresponding approximately to the positions that the bosses will occupy in the forging.

There are very substantial reasons for this preliminary distribution of metal. First, the productive life of the die blocks is prolonged by removing from the impressions the burden of this mass movement of metal. Second, by distributing the metal in masses to the approximate position required by the impressions in the dies, the formation of a true, sound forging is promoted. Fig. 3 shows the next forging step. It will be observed that this operation is an extension of the preceding operation. The original uniform section of the bar has now become a nonuniform section in which the metal has been distributed as masses into positions from which the forging impression can work or mold these masses into the desired finished shape. Particular attention is called to the boss indicated by the arrow. The formation of a forging defect, known as a "lap" is in progress.

The section of the partially formed forging as it comes from the first

---

A paper to be presented at the New York Sectional Meeting, March 3. The author, J. H. G. Williams, is assistant works manager, Billings & Spencer, Hartford, Conn.

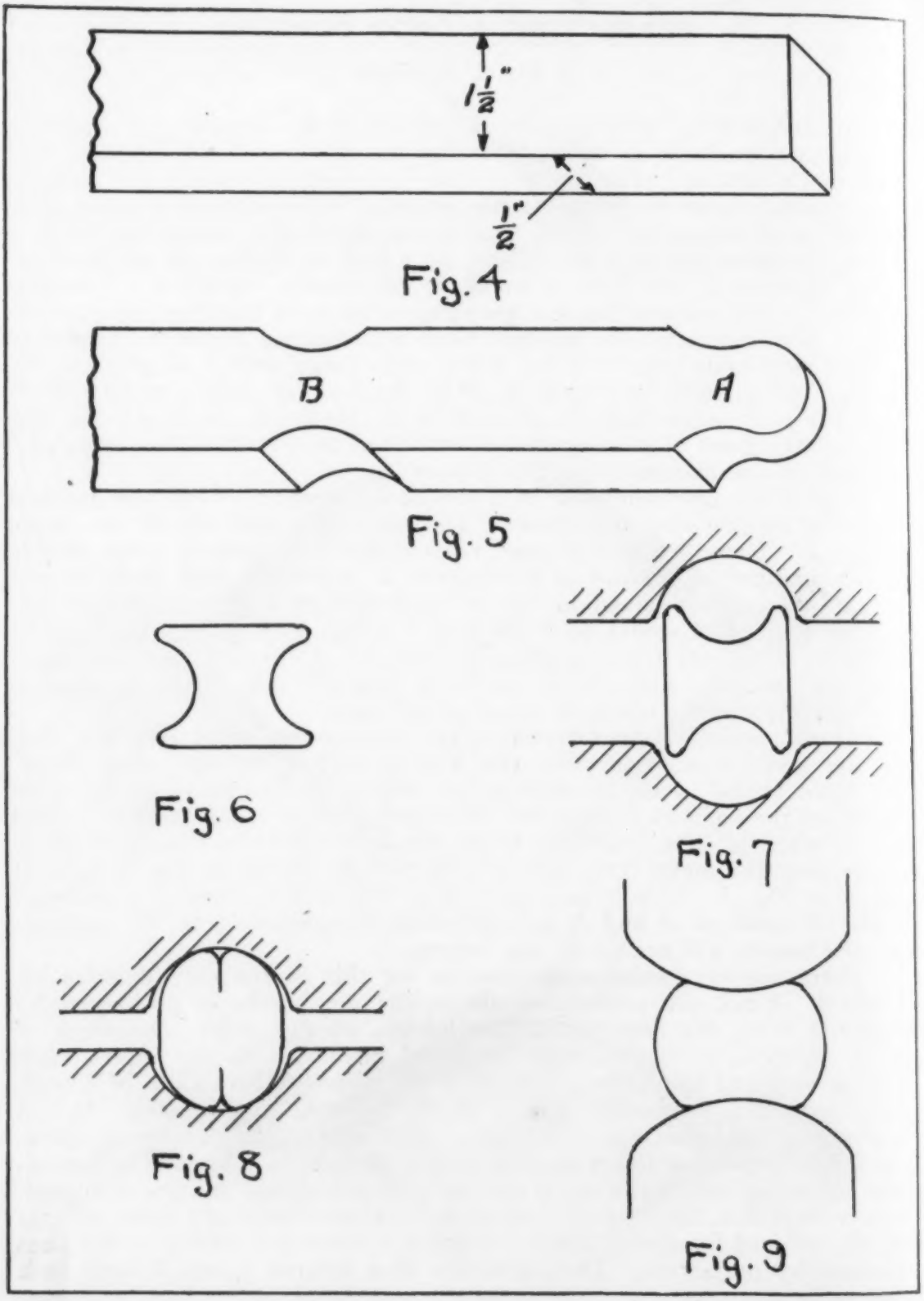


Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 9

Fig. 4—A specimen of the stock used in producing the drop forged part. Fig. 5—The uniform section of Fig. 4 is redistributed as shown, metal being massed at *A* and *B* at the approximate positions the bosses will occupy. Fig. 6—The section of the partially formed forging as it comes from the first or "edger" operation. Fig. 7—For the second or "rough blank" operation, the piece is given a quarter turn. Fig. 8—The lips of the cup-like section shown in Fig. 7 are lapped over by the pressure of the dies. A photograph of this operation is shown in Fig. 3. Fig. 9—To eliminate the lapping effect, the edger may be rounded off somewhat as shown

or "edger" operation is something like Fig. 6. When placed under the dies for the second or "rough blank" operation, it is given a quarter turn so that the cup shape faces the impression, Fig. 7. The action of the dies upon the lips of the cup-like section is to lap them over somewhat as shown in Fig. 8, and it was the photographic representation of this action that was illustrated upon Fig. 3.

In order to eliminate this lap, it is necessary to modify the impression which changes the shape of the bar stock. Because this impression is sunk in the edge of the dies, both the operation and the impression, are referred to as the edger. It is clear enough that the desired redistribution of metal must be accomplished without the formation of the cup shape section of Fig. 6. The edger may be rounded off somewhat, forming a section somewhat resembling Fig. 9, and this latter section will be found to operate under the rough blank impressions without the formation of a forging defect.

As a matter of fact, these laps were eliminated by omitting the use of the edgers. It was found after making the first dozen forgings, that the bar stock could be placed between the "breakdown" impressions, and produce the shape shown in Fig. 3, without the necessity for any previous preparation of stock, and without the formation of any laps. Fig. 10 is a close up of the laps just described. The rough blank shown in Fig. 3 is transferred to the finishing impressions, and emerges in the form shown in Fig. 11. This forging is ready to have the flash trimmed off and the center punched out.

Another interesting and at the same time instructive type of defect appeared at points *A*, Fig. 11. After trimming, the forging was found to be split at the flash line. Defects of this nature are common with piped stock, but an extended examination of the raw material demonstrated that the bar stock was sound and homogeneous. Figs. 12 and 13 show a magnified view of the metal in the vicinity of the split. The heavy black streak is iron oxide. It was noticed that this split was just above the flash line instead of in the center of the flash line as would be expected if the defect were due to the material itself.

Fig. 14 shows a section of the forging that explains the formation of the defect. Any section of the blank must contain a greater area than the corresponding section of the finished piece. The forging operation consists of forcing out the excess metal while forcing the required metal into the shape contained by the impressions. As a direct result, this excess metal must flow sideways into the flash, that is, the excess will flow toward the outside, and toward the inside of the forging.

The laps in the center at *A* Fig. 14 illustrate waves or undulations of excess metal that traveled toward the center under the effect of each blow of the hammer, where they were folded over and compressed. Now, when this central web of metal is compressed by the blows of the hammer, the metal has no opportunity to flow elsewhere than to the outside, and in so doing must pass through the arms of the forging. The effect of a flow such as just described is to fold the surface into the forging proper. This condition is shown by the black spots just above and below the flash on the right side of the forging in Fig. 14, and also by the black streak in the left side. When the excess metal is trimmed off, the

forgings will show splits or separations of metal at *B*, just above the flash line.

Several methods are used for removing the conditions which promote the formation of these defects and all are based upon the principle of providing a central space into which the excess metal may flow. For instance, the center can be punched out, or the thickness of the cen-

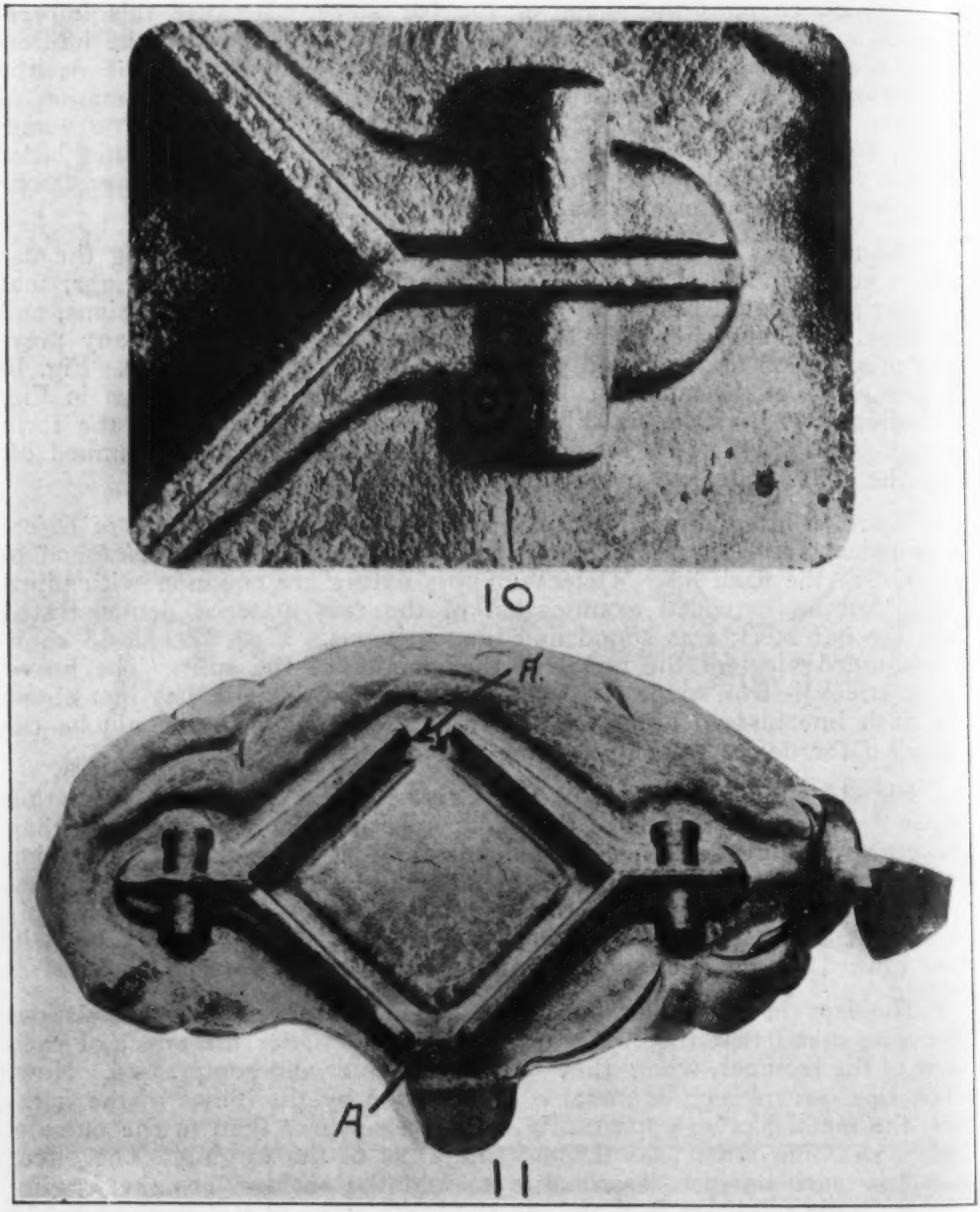
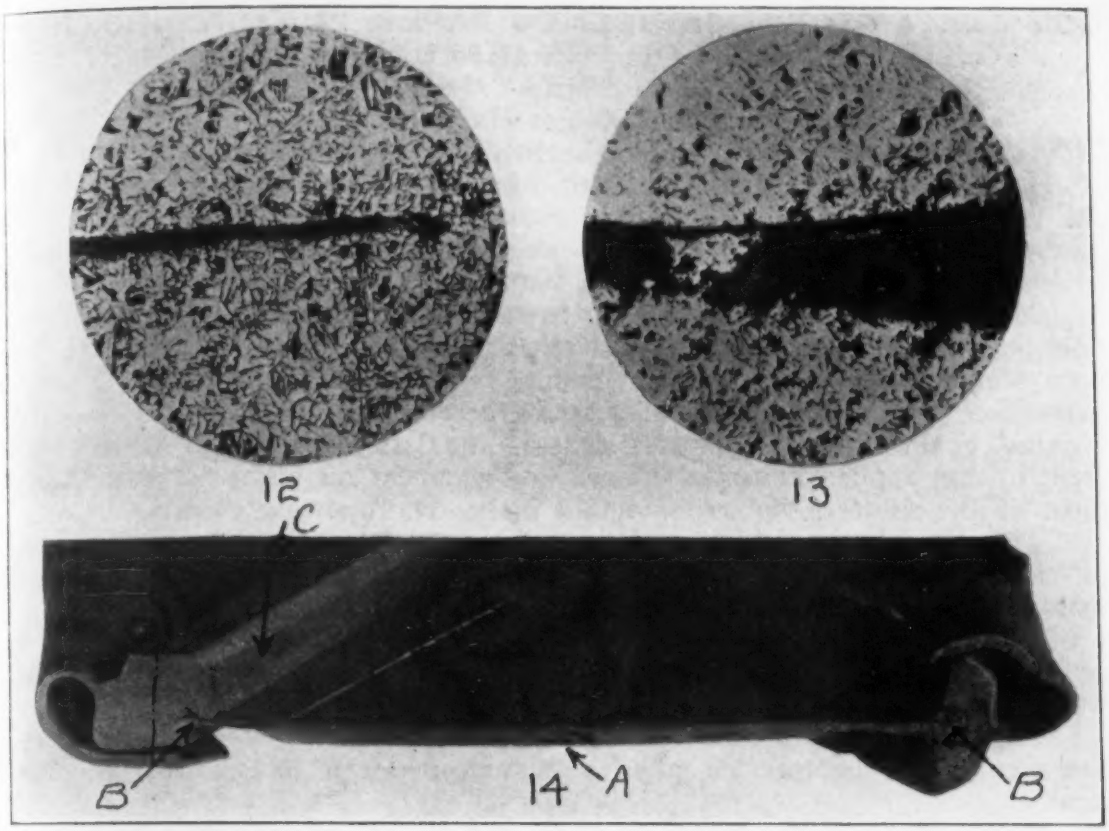


Fig. 10—A close up of the laps formed as shown in Fig. 8. Fig. 11—After trimming, the forging was found to be split at the flash line as indicated by *A*



Figs. 12 and 13—A magnified view of the metal in the vicinity of the split shown in Fig. 11. X 100. The heavy black line is iron oxide. Fig. 14—A section of the forging which explains the formation of the split defect. The illustration is about twice actual size

tral web may be forged undersize previous to finish forging, or the bosses in the finish impression may be hollowed out.

Fig. 14 also illustrates one more forging defect, known as "mismatching". Referring to the arm on the left, it is obvious that the lower or bottom part of the forging is not symmetrical with the upper or top portion. A defect of this character is due to the upper and lower die blocks being slightly out of alignment. This photograph also demonstrates that the upper die impression shaved the edge of the blank, and formed the lap which is so clearly evident. While the lap was being folded over and pressed down, the metal in the central web was flowing toward the outside, and the inner surface of the lap and the upper surface of the web were pushed into the interior of the forging as indicated by the black streak at *B*.

The first forging produced after a hammer set up is carefully examined for forging defects, and adjustments or alterations are made to overcome the objectionable features. By carefully checking up each forging during this period of adjustment, the dies are finally brought into a condition such that a continuous run of perfect forgings may be produced.

COMMENTS ON E. J. JANITZKY'S PAPER, "A CONTRIBUTION TO THE PROBLEM OF THE INFLUENCE OF MASS IN HEAT TREATMENT

By Sir Robert Hadfield

THE paper, "A Contribution to the Problem of the Influence of Mass in Heat Treatment," by E. J. Janitzky, which was published on page 55 of the October, 1921 issue of TRANSACTIONS deals with an interesting point. There is no doubt that if the mass effect in heat treatment can be made to lend itself to calculation, the data so obtained will be very useful.

Mass effect operates mainly in two different connections: (a) By influencing the time necessary to heat an article through to its center to an even temperature in the furnace; and (b) by influencing the rate of heat extraction in cooling operations, and thereby the hardness and other physical qualities of the material. It is the latter feature to which Mr. Janitzky has applied himself. By way of comment on his method of treatment of the subject, the writer would make the following remarks.

The initial basis of his calculations shown in formula (2), page 57, is a physical one. It is questionable, however, whether it is right to assume that the hardness, or the increase of hardness produced by rapid cooling $(B\text{-}b)$, has a linear relationship with the surface per pound of steel. In order to establish a scientific formula, and not merely an empirical one, it would be necessary to look more closely into this relationship.

The introduction of the term d renders the working formula (4) entirely empirical, because no physical significance can be assigned to this term.

Empirical formulas, however, often can be of service in metallurgical calculations providing the constants obtained are either invariably the same, or a definite constant can be assigned for any particular set of conditions including the type of material worked with.

In Mr. Janitzky's calculations the value of d varies, and if it is desired to apply this hyperbolic formula to any particular case it is necessary to ascertain the values both of b and d for that particular case, which can only be done by previously having at least three experimental observations with one particular treatment on three different sizes of bars. A fair estimate might then be made of the hardness to be obtained from any other size of bar within or not appreciably outside these limits. The utility of the formula is therefore very limited.

The value of b in each case examined by Mr. Janitzky is given as 175 which would appear to be a constant figure for 0.45 per cent carbon steel under varying conditions of treatment. It is difficult to see, however, how such a uniform figure has been arrived at. Close calculation of the untempered, water quenched, and oil quenched specimens, cases (1) and (4), gives the following figures:

Case No.	Treatment	Value of b	Value of d
1	Water quenched	214.4	0.49
4	Oil quenched	142.9	3.86

There is thus a very considerable difference between the values of b obtained by strict application of the formula, for the same steel. This further demonstrates the empirical nature of the formula, because, if it has a

---

The author, Sir Robert Hadfield, is chairman Hadfields, Ltd., 22 Carlton House, London Eng. Many of these criticisms are answered in a new paper by Mr. Janitzky, which appears on page 377 of this issue of TRANSACTIONS.

physical significance, it represents in both cases the hardness produced by an exceedingly slow rate of cooling, and the two figures therefore should be identical.

It should be carefully borne in mind that there is often considerable latitude in the selection of empirical formulae to suit a series of physical data. The applicability of Mr. Janitzky's hyperbolic formula, therefore, especially as it contains arbitrary constants, must in no way be regarded as a vindication of the physical hypotheses taken as the starting point.

Mr. Janitzky, however, has done a service in looking into this question, and his calculations will, it may be hoped, lead others to investigate the subject further.

INFLUENCE OF THE HEATING MEDIUM ON THE STRUCTURAL CHANGES IN STEEL

By A. E. Bellis

IN TREATING steel the practical man's object is to change its properties from a soft and ductile metal to a hard and brittle one, or vice versa. The degree of change and the skill with which the desired properties are obtained, measures his skill as a heat treater. In scientific terms, the metallurgist speaks of changing the structure of his steel and he uses all the tools of science to control and identify these changes. In this paper, a more or less scientific analysis is presented of these structural changes as they are influenced by the heating and cooling medium. Special emphasis is to be given to the results as expressed in the shop man's terms of strength, hardness, toughness, brittleness, etc.

The fact that the rate of heating or cooling is the fundamental factor in changing the properties or structure of steel is rarely given the consideration that its significance warrants. It isn't the temperature to which a piece is heated that is of such fundamental importance as it is the rate at which a piece cools from that temperature which determines its structure and properties. Of course, it is necessary to exceed the critical temperatures of the steel, to change the temperature. It is an interesting point to bring out that it has been shown by some recent research work that the critical temperatures that we usually speak of as landmarks vary if the cooling or heating rate is slower or faster. Those critical temperatures which we have thought of as a definite figure are not a definite figure, but they vary with the rate at which the temperature changes, thus the critical point given for a certain analysis steel is not of any value unless the rate of heating and other dependent data are given:

The importance of considering the abstract idea of rate of heating rather than of concrete temperatures is apparent on going over the heat treatment of a carbon steel cutting tool, keeping an eye on the time effect. The tool is heated slowly to, say 1400 degrees Fahr., kept there just long enough to know that it is all at that temperature and then very rapidly cooled down to 750 degrees Fahr. or thereabouts. By the rapid cooling the physical condition reached at the high temperature is to a great extent maintained, with corresponding properties and structure of hardened steel. The steel is now in a very unstable condition and has a strong tendency to change to a more stable form which happens to be softer, the annealed state being the really completely stable form at room temperature. It is out of equilibrium and will "obey that impulse" to change gradually back to the stable state if it is heated. So we draw it. We heat it up to a temperature where it can ease back toward the softer state of comparative equilibrium and keep it at that temperature until it reaches the exact condition we desire.

If the work is slowly heated to a relatively low temperature in tempering, different results are obtained than by heating rapidly even to higher temperatures. The rates of heating and cooling are obviously very important and depend entirely on the surrounding medium of solid liquid or gas. In the open fire or muffle furnace, where the heating

---

A paper presented at the Indianapolis Convention. The author, A. E. Bellis, is president, Bellis Heat Treating Co., New Haven, Conn.

medium is a gas, the heat is conducted from the flame rapidly at points of contact or transmitted slowly by radiation through an oxidizing and poorly conducting gas. The heating then is far from uniform, and difficult.

When the work is surrounded by packing material the heating is by conduction through the solid material. In this method the disadvantage of oxidation is eliminated to a great extent but its disadvantages and difficulties are well known. If the medium is a mobile liquid of high specific heat the mechanism of the heat transference between the medium and the work is altogether different. By convection currents the liquid is kept moving past the work and new portions of the bath, at the temperature of the bath, are always in contact with the work. Thus the heat flows uniformly into the work from all directions. The conductivity of the bath material is not a factor as it is negligible alongside of the continual intimate mixing of the liquid. The specific heat, or heat-storing-capacity, obviously is a controlling factor.

Of liquid heating and cooling media the ones most used are, of course, water and oil. It is interesting to note at this point that mercury is not as effective a quench as water. Although its conductivity is high, its specific heat is much smaller than water. In the same way the perfected salt bath is more effective as a quench than the lead bath. We have found that more complete hardening results from quenching in the perfected salt bath at temperatures up to 1350 degrees Fahr. than can be obtained from quenching in lead at 1000 degrees Fahr. This medium is a salt bath which started with a barium bath, but this was discarded about five years ago, 1916 to be exact, and we have been doing research work on it ever since. We have gone a long way from the original point, and our present bath will be mentioned here several times as the "perfected salt bath." This perfected salt bath is not to be confused with the many other salt baths that are on the market and have been tried for a good many years.

On a cold day metals feel cold because they conduct the heat away from your hand quickly in spite of their low specific heats. Stones, although their specific heat is many times as large, conduct the heat away slowly, and hence do not feel as cold. Thus, one might thoughtlessly conclude that a liquid metal would be a more effective quench than a molten stone. However, a little thought shows that this is not so. The quantities of heat concerned in the first instance are so small that the specific heat does not enter into consideration. In the latter case it is of paramount importance, and the formerly important factor, the conductivity, is now negligible, the materials being mobile liquids.

Applying these principles to the hardening of high speed steel, we find it not only possible to quench effectively at a high temperature, as mentioned above, but greatly advantageous. Hardened high speed steel is unstable and has a strong tendency to change into the annealed state. The word stable here in a different manner from which Mr. O'Neil, I believe it was, used it in speaking of high speed steel. It is a technical term used in theoretical chemistry, but I think its meaning will be brought out by the way it is used. If hardened high speed steel is heated, it becomes annealed to a degree depending on the temperature and length of time at that temperature. It has the impulse to change to

that annealed form. We heat it up and it starts changing, and as soon as we have it at the point desired, heating is stopped.

The conventional treatment of a high speed steel tool is to heat it to, say 2300 degrees Fahr., quench it at room temperature, and reheat for a time to 1000 degrees Fahr. or thereabouts. The steel is vigorously jerked out of equilibrium and then allowed to ease back to the point desired. This is like stretching a rubber band to the breaking point and then letting it shorten to the final desired length. The damage, distortion, cracking, etc., is done in the quenching, jerking it so far out of its state of equilibrium and subjecting it to a sudden change of temperature of 2000 degrees or more.

Why do we not put it immediately into the state we want instead of straining the tool by over-shooting? Because, heretofore the only way to get sufficient speed of cooling, or rather the correct speed of cooling, past the critical temperature has been to have the temperature difference between the tool and the cooling medium very great, approximately 2000 degrees. If we could put it into the state we wanted directly, it would be very convenient, and it has been tried a good many times, but it has been found impossible. Experimenters have tried, as Mr. D'Arcambal has said, to quench it at 1100 degrees Fahr. in oil to obtain that effect. They found that it was impossible to get the best results that way because the rates of heating and cooling used were not correct. The exact rate of heating and cooling of any part of the tool is something that it is practically impossible ever to know. You can determine the temperature at any given time, but there is always a lag in the pyrometer. These lags are very great sometimes, and the speed of cooling is great. If it is a little too great or a little too small you do not get the correct effect.

The rate of cooling is dependent upon the temperature difference between the work and the contiguous part of the medium. If the medium does not circulate freely, that part next to the work quickly becomes nearly as hot as the metal, and the temperature difference becomes small. If, however, the medium is a very fluid liquid moving past the piece, the temperature difference between the work and the contiguous part of the bath is practically as great as between the average temperatures of each, and the heat transfer is so facilitated that sufficiently rapid cooling takes place if the specific heat is great enough, in quenching at 1000 degrees Fahr. or higher.

Temperature change of the tool per minute is proportional to the quantity of heat removed per minute, which is in turn proportional to the temperature difference between the tool and the contiguous portion of the bath, provided the bath has sufficient heat absorbing capacity per unit volume.

The efficacy of the quench depends on speedy removal of a quantity of heat, ending up at a temperature only sufficiently low that the tendency to reach equilibrium is controllable. That is to say, we want to get the effect that is usually obtained by quenching in oil and then drawing, and what we want at the end is to have the steel stable at 1000 degrees Fahr. No matter what method is used, you end up at 1100 degrees Fahr., because high speed steel, to be good, must have a chronic structure at that temperature. Distortion is due to the great change in temperature, therefore, what we want is a speedy cooling

only down to the point where danger of overdrawing is past. This can now be accomplished in the perfected salt bath. This method has the additional commercial advantage of eliminating one operation, the draw.

Lead at 1000 degrees Fahr. has been used for quenching high speed steel and found to be not entirely satisfactory. This is because its specific heat is so small that the addition of a little heat from the work raises the temperature of the lead locally to such an extent that the temperature difference between the work and the medium is so reduced as to cut down the rate of cooling to cause hardening uncertain.

This paper has been boiled down to that point, and will be left the way it is, except for one or two facts further. The authors intended to have a large table of statistics, but we hadn't obtained the data at the last minute, and it was necessary to take this rough report, which showed an increase of 20 per cent, consistently, not in speeds or feeds, but in inches of material cut before the material dulled. We have not conducted any tests pieces to speak of, and we have not used the Brinell or scleroscope instruments a great deal. All the results are based on the work that the tool does before it gets dull, the speed at which it will work and the amount of material that it will cut. That is the final objective, and that is what we have been working for directly without taking any middle steps. The whole object has been to get this red hardness, this tool which will work at 1100 degrees Fahr. and do the work and do more work than has been done before.

Also the rate of cooling from the salt bath in the water, for instance, on carbon steel is controlled by the film of salt which stays on the tool. When it is taken out of the salt bath, it has a slight film of salt on it. There are possibly several thousand analyses of salt baths. If you get exactly the right one, you have a peculiar film on the tool that has the peculiarity that when it is put in the water, the speed of cooling will be controlled, so that you will obtain the hardness without over-straining the tool.

Discussion of Mr. Bellis' Paper

MR. D'ARCAMBAL: You say you gained 20 per cent over what? In cutting tests?

MR. BELLIS: That 20 per cent, I haven't the figures of speeds and feeds, was in the inches of material cut before the tool needed regrinding.

MR. D'ARCAMBAL: What do you mean?

MR. BELLIS: Twenty per cent increase in the number of inches the tool will cut.

MR. SAWTER: Do you mean to say that your molten salt bath will conduct heat away quicker than hot lead will?

MR. BELLIS: Much quicker.

MR. SAWTER: How much quicker?

MR. BELLIS: Well, of course it is hard to say how much quicker without figuring it out. On two particular pieces you could try that. It would depend on the size of the piece and the temperature. You know that the specific heat of lead is about one-tenth that of the salt bath. It is about one-tenth of almost any salt bath. The specific heat of the salt bath is 0.20 or 0.30, and the specific heat of lead is 0.03, and the density of the lead, of course, is five times as great. That is in favor of lead. But the salt bath has a specific heat ten times as great, and one-fifth as much specific gravity; its heat capacity per unit vol-

ume is just twice as great as lead. Therefore, if you take any one moment during the cooling, there is some of the salt immediately against the piece, and the heat flows from the piece into the salt. In so flowing it raises the temperature of the salt. Now if the specific heat is twice as great, it will raise that temperature just one-half as fast and the faster that rises, the slower it will cool.

MR. SAWTER: What about your conduction?

MR. BELLIS: It is conduction just at that point, but conduction through the bath doesn't have any appreciable affect, because the bath is continually mixing.

MR. SAWTER: Also I would like to ask the question as to the comparison of the cost of maintenance over gas fired and oil fired.

MR. BELLIS: I couldn't give you exact figures on the cost of maintenance, but the last figures that I saw that would be at all comparable to that were prices on chaser dies, threading machine dies. A cost account was kept for those and we found that in treating them in the salt, of course—by the way, the results were a great deal better because of the lack of distortion, etc.,— the cost of treating them in the salts was less than it was the other way, but it was principally, I believe, due to the fact that it was done a great deal quicker. They would have the salt baths in a row; for instance, in the high speed work we have the pre-heat, the high heat and the quench and the dies are moved at two or three-minute intervals, according to the size of the piece, from one bath to the next. It is a continuous operation, and the time is reduced to such an extent the cost of heat treating the die is much less than it would otherwise be.

MR. D'ARCAMBAL: Taylor, in his experiments 20 years ago found that the rate of cooling after heating to the quenching temperature made absolutely no difference to it. The whole thing depended on the quenching temperature. We have tried to verify that, as far as hardness goes. We took two pieces from the same bar of steel, one we buried in lime after heating to 2350 degrees Fahr. and the other we quenched in ice water, and both were file hard and had exactly the same microstructure.

MR. BELLIS: The only time I can think of that being true is in the old Mushet steel. Every one knows that if high speed steel is cooled slowly enough, it will not be hard.

MR. D'ARCAMBAL: We threw a piece in lime and let it cool.

MR. BELLIS: If you let it cool and take 24 hours to get down it will be annealed.

MR. D'ARCAMBAL: I don't agree with you on the rate of cooling.

MR. BELLIS: If high speed steel is heated to 2300 degrees Fahr. and cooled slowly enough, it will be annealed when it is cooled. If you cool it quickly, it will be hard.

MR. D'ARCAMBAL: I am comparing a one-minute cooling with about an hour's cooling.

MR. BELLIS: It is just a case of taking it to the extreme to show the rate does have an effect. That is my point.

CHAIRMAN FOLEY: I think Mr. D'Arcambal's idea is that it remains austenitic. If you reduce it very rapidly or very closely, it still remains austenitic.

MR. BELLIS: My point is that we wanted to produce the method that gives results and we have now done it.

CYANAMIDE IN LIQUID CASE HARDENING

By P. W. Shimer and E. B. Shimer

USE of calcium cyanamide for case hardening, by reason of its high carbon and nitrogen content, suggests itself very naturally to the metallurgical chemist. Its use for this purpose, therefore, dates back at least 16 years, when a patent was granted to Gustav Deininger, of Berlin, Germany, for its use in a pack hardening mixture.

When in 1915, because of the scarcity and extremely high price of sodium cyanide, the authors began experiments with commercial cyanamid in liquid case hardening, it was soon found that, on account of the interminable frothing caused by its addition to mixtures of fused salts, and because of the thickening and clogging up of the melt by reason of the residual material left in it, its use was impracticable in this form. After a good deal of experimenting in the laboratory the idea was conceived of combining the powdered cyanamid in proper proportions with a hard pulverized pitch and coking the mixture at a high temperature. (U. S. Patent No. 1279458). In the laboratory use of this coked mass, in lump form, in various mixtures of salts having suitable melting points, the frothing and other troubles were overcome. In its first commercial application, the Ingersoll-Rand Co., of Phillipsburg, N. J., coked in their furnaces the mixtures of cyanamid and pitch prepared in our laboratory and used it successfully with the mixture of salts through the emergency caused by the very high cost of sodium cyanide during the war. In further laboratory researches and experiments it was found if we used hard, well converted calcium cyanamide, canned and sealed as fresh as possible from the furnace in which it was made, that we could use this in lump form to replace our coke with important advantages. (U. S. Patent No. 1279457).

While these two processes were first developed in all their essential details in the authors' private laboratories and furnaces, the first use in a commercial way was by the Ingersoll-Rand Co.; and they have used it continuously and successfully for over five years. We desire to acknowledge our indebtedness to John Halbing, superintendent of the heat treating department of that company and his assistants, for their co-operation in this work. Efforts to introduce the process to more general use were undertaken comparatively recently and only in a conservative manner. The first publication was made in a paper on "The Shimer Case Hardening Process", read by Dr. Joseph W. Richards, professor of metallurgy, Lehigh University, before the American Institute of Mining and Metallurgical Engineers in February, 1919.

In this process two materials are used:

1.—The special lump calcium cyanamide to which has been given a registered trade name. It has a high content of carbon and nitrogen, both of which elements are essential in liquid case hardening. It is a hard, infusible, rock-like material, black in color and lighter than the melt in which it is used. When perfectly protected from atmospheric moisture, it remains hard for an indefinite time; a sealed can of it recently opened was hard and unaffected after over two years storage. When exposed to air, however, it gradually softens and finally falls to powder,

A paper presented by title at the Indianapolis Convention. The authors, P. W. Shimer and E. B. Shimer, are consulting metallurgical engineers, P. W. Shimer & Son, Easton, Pa.

acting in all respects like air-slacked lime. It is of first importance, therefore, to protect this material as far as possible from atmospheric moisture, for if it becomes soft, it disintegrates in the melt, causing frothing and a heavy scum on the surface.

2.—The easily fusible mixture of salts, with no case hardening properties, given a registered trade name, is a mixture in proper proportions of pure dry calcium chloride and sodium chloride of suitable purity and physical properties. In laboratory tests, other mixtures have been used successfully but, for the present, at least, the mixture now used is probably the best for general purposes. Among its advantages are that it is cheap and that it permits the use of the higher temperatures with but little loss by volatilization. It has a melting point of about 1150 degrees Fahr. The material is, however, hygroscopic and must be kept well covered to prevent the taking up of air-moisture. With a little care to keep containers covered, there will be no trouble with these materials.

In carrying out the process, the same furnaces and pots employed in cyanide hardening, generally, may be used. The only additional equipment necessary is a perforated metal basket for holding the cyanamide and sinking it to the bottom of the melt. The amount of the material commonly used to impart case hardening properties to the inert fusible salt bath is 5 per cent of the weight of bath needed to fill the pot to the required depth. The basket is easily made of perforated metal, with perforations about ¼-inch in diameter, and of a shape conforming to the shape of the bottom of the pot, but with sufficient play all around so as to insure easy removal. The baskets should be only high enough to hold the necessary amount of cyanamide so as not to lessen too much the available depth of the pot. The basket must be provided with an easily removable perforated cover which must be well fastened down, otherwise the cyanamide will float out. When such a basket of proper size and shape is used, the case hardening combinations are formed over the whole bottom of the pot, from which the generated gases convey them uniformly up and throughout the melt. The size of the cyanamide pieces varies with the size of the pot, but in all cases, they should be freed from powder and soft material, for these may cause frothing. The melt penetrates the hard cyanamide very slowly and it is often advantageous, after a day's run, to break the larger pieces into two or three smaller ones. This exposes fresh surfaces and another days run often may be secured from this broken material. When breaking up cyanamide by hand, it is well to use gloves, for the powder is irritating to chapped or abraded skin. The manufacturers of the material protect the hands of their workmen by use of vaseline. The activity of the bath is directly proportional to the surface exposed. Since the smaller pieces expose several times as much surface in proportion to their weight as the larger ones, it is sometimes well to take advantage of this when extra quick action is desired, or when toward the end of a day's run, it is desired to boost the strength quickly. This may be accomplished by use of smaller baskets filled with coarse granules of the material, which may be let into the melt on top of the large basket at the bottom. Commonly the size of cyanamide used in the large basket varies from ¼ to 2 inches in diameter.

Since in this process, as well as in the cyanide process, the oxidizing action of the air on the surface of the melt is destructive to the case

hardening compounds, it is well to keep the pot covered closely when not actually in use. For this reason the black scum which sometimes comes to the surface of the melt is not without certain advantages, for it protects the melt from the air and, when used at the higher temperatures, lessens loss by volatilization. It also lessens radiation of heat from the surface of the melt and to that extent saves fuel.

It may be added here that in the laboratory experiments, it was found that, when the 5 per cent of cyanamide, instead of being added at one time and in coarse pieces, is added at intervals in five wire-enclosed charges, containing each 1 per cent of the weight of the melt of coarse granules, there is a marked economy and maximum case hardening results per unit of material are secured. When, in these experiments, the melt was covered so as to protect it from the oxidizing action of the air, there was still further marked economy.

Before lowering the basket of cyanamide into the melt it must, of course, be hot and dry to prevent sputtering out of particles of the melt. This is especially true when material from the preceding day's melt adheres to the basket. It must then be thoroughly preheated either on the furnace or in a preheating furnace, if one is conveniently at hand. This drying of the basket may be simplified if the precaution is taken to place it in a suitable can or other receptacle provided with a tight cover as soon as possible after removal from the bath.

Immediately after the basket is lowered into the pot the bath begins to show activity and after a short time there is a rapid evolution of gases upon the surface, which at the height of activity, covers the top with numerous small yellow flames. The strength of the bath may be judged from the activity of this evolution of gases upon the surface. As the case hardening strength dies down, the bath becomes more quiet. Until quite familiar with the appearance of the bath, it is well to test its case hardening strength by testing it upon a nail at intervals.

The temperatures commonly employed vary from 1425 to 1700 degrees Fahr., usually about 1450 degrees Fahr. The deeper cases, up to 1/32-inch, are obtained in from 1½ to 2 hours at the higher temperatures. After quenching, the steel must be treated with a hot solution of soda ash. This is important, for the trace of calcium chloride which remains on the steel after quenching facilitates rusting. The hot soda ash solution decomposes this trace of calcium chloride and converts it into harmless calcium carbonate. Another advantage of this treatment is that the steel on removal from the hot solution dries rapidly.

When the basket of cyanamide is nearly exhausted, it is lifted out of the melt and replaced by a fresh basket. When the basket is provided with an easily replaceable cover, the material may be dumped out immediately after removal from the pot and fresh cyanamide may be filled into the hot basket. On examination of the spent cyanamide the pieces will be found to have preserved their original size and shape. The fusible salt bath has simply removed from them their case hardening elements, thereby leaving the inert residue. Of course, new bath mixture must be added from time to time to keep up the level of the pot and to replace that which is carried out by adhering to the work. On account of the thinly liquid character of the bath at the case hardening temperatures, this loss is reduced to a minimum. Upon quenching, this thin film flies off instantly, leaving the work with a clean surface.

To determine the nature of the gases given off from the active melt,

they were collected under a bell-shaped iron casting, the rim of which was immersed in the melt. From this bell they were led off and collected in large two-gallon bottles for chemical analysis. This operation was repeated so that a comparison could be made of the gases given off on different days and under slightly different conditions. The results follow:

Test No.	Nitrogen	Carbon monoxide	Carbon dioxide
	per cent	per cent	per cent
1	69.5	26.0	4.5
2	80.8	19.0	0.2

A careful cyanogen test was made on a sample of six liters of the gas, but no trace of it could be found. This result is confirmed by the fact that there is absolutely no odor, or any gas of an irritating character, given off from the melt. The carbon monoxide burns on the surface of the pot and the only gases finally given off into the shop are harmless nitrogen and carbon dioxide. This absolute freedom from every trace of poisonous and irritating gas is a great source of safety and comfort to the workmen.

It would be interesting to know all the chemical reactions which go on in the melt and a good deal of work has been done to determine them. As a result we have some pretty well defined ideas of what goes on when the fusible salt bath and cyanamide react at high temperatures and when in turn the resultant compounds react with the oxygen of the air. However, we feel sure that the remarkable case hardening activity of the bath is due in part, at least, to the fact that the case hardening elements are in a nascent state and are therefore peculiarily active. In the same bath and at the same time in which the compounds are interacting to form case hardening combinations, the steel is present to take up the nascently active carbon and nitrogen.

To get comparative results between cyanamide and sodium cyanide, the following experiments were made in a small gas-fired furnace in the laboratory, using a deep pressed steel pot holding 20 pounds of melt. The steel used was a simple steel and the pieces were 1-inch in diameter and 5 inches long. The turnings made in turning down the pieces were preserved and part of them were case hardened along with the steel pieces.

Experiment 1.—Twenty pounds of bath mixture were melted down and a perforated cast-iron basket containing one pound of cyanamide in small pieces was sunk to the bottom of the pot. When the temperature had reached 1526 degrees Fahr. the piece of steel and the wire basket of turnings were immersed in the melt and left there for one hour at that temperature. The piece of steel was then removed and annealed by allowing it to cool at the bottom of the ladle full of the melt in which it was removed from the pot. This also allowed the cooling to take place with absolute exclusion of air. The turnings were quenched in water and thoroughly cleaned and carefully dried for analysis. During the whole hour of the experiment the pot was kept covered as closely as possible.

Experiment 2.—This experiment was a continuation of Experiment 1, the only difference being that the pot was uncovered during the hour of its duration. The same temperature, 1526 degrees Fahr. was maintained and the second steel piece and turnings were similarly treated.

Experiment 3.—A clean steel pot of the same dimensions as in the

first two experiments was used; the pot had been used before for case hardening. It was filled with pure sodium cyanide without other admixture, and the time and temperature were the same as in the first two experiments. The third piece of steel, and turnings also, were treated exactly as before. As in Experiment 1 the pot was closely covered during the whole hour.

Experiment 4.—This was a continuation of Experiment 3, the only difference being the removal of the cover from the pot. The fourth piece of steel and turnings were treated as before for one hour.

The steel used had the following composition:

	Per cent
Carbon	0.092
Silicon	0.185
Sulphur	0.036
Phosphorus	0.012
Manganese	0.402

The turnings after case hardening as above contained carbon as follows:

Experiment No.	Treatment	Per cent
1	Cyanamide covered	1.39
2	Cyanamide uncovered	0.806
3	Cyanide covered	0.796
4	Cyanide uncovered	0.712

The case hardened pieces were turned up in such a way that we got an approximate first cut of 1/200 inch, a second cut of 1/100 inch and a third cut of 1/100 inch in each of the four experiments. Careful determinations of carbon and nitrogen were made in each set of turnings. As an extra precaution against incomplete combustion and other possible errors, the carbon determinations were made by the standard method of solution and combustion.

The carbon and nitrogen results are as follows:

Cut No.	Depth of cut inch	Carbon per cent	Nitrogen per cent
Experiment 1, Cyanamide Covered			
1	1/200	0.754	0.301
2	1/100	0.254	0.041
3	1/100	0.160	0.039
Experiment 2, Cyanamide Uncovered			
1	1/200	0.576	0.220
2	1/100	0.472	0.140
3	1/100	0.188	0.024
Experiment 3, Cyanide Covered			
1	1/200	0.622	0.351
2	1/100	0.268	0.081
3	1/100	0.108	0.028
Experiment 4, Cyanide Uncovered			
1	1/200	0.528	0.240
2	1/100	0.180	0.060
3	1/100	0.128	0.028

Prof. Henry Fay, of the Massachusetts Institute of Technology, finds that nitrogen is present in all case hardened steel, especially steel treated by the liquid melt processes. He finds also that at the higher temperatures, the amount of nitrogen taken up is considerably less than at ordinary case hardening temperatures. In this process we, as well as other investigators, have found consistently higher carbons and lower nitrogens than in the cyanide process, time and temperatures being the same.

An application of the process which is being made with success is its

use as a heating bath in place of lead for certain classes of work. The advantages of a heating bath of fused salts are several: 1. Its low specific gravity as compared with lead allows the work to be suspended freely in it; 2, the slower heating lessens distortion of pieces of intricate design and with heavy and thin sections of metal; 3, the work comes out of the water quench clean and bright. From the lead bath the work often comes covered in spots with lead and dross which is hard to remove, especially from threaded parts. The parts under the adhering lead also remain soft, after quenching. A disadvantage, however, of a heating bath of fused salts, is that the baths have a slight decarburizing action on the steel. This we have overcome simply by introducing into the bath a small basket holding not more than 1 per cent of the weight of the melt of cyanamide. Or, if cyanamide case hardening is going on near by, an occasional small ladle of the case hardening bath added to the heating bath will answer the same purpose. By this procedure just enough carburizing activity is imparted to the heating bath to counteract the decarburizing action and not enough to cause case hardening to any undesired extent.

When an oil quench is used on steel heated in a heating bath of salts, the work is more difficult to clean than work quenched from a lead bath; on water quenched work the advantage in cleaning is with the salt heating bath. We may add, at this point, that the fusible salt bath may be used to great advantage as a fusible cover for lead pots in place of charcoal. Enough of it is placed on the well cleaned lead to cover it to a depth of about ½ inch. This works admirably for water quenched work; oil quenched work is difficult to clean and for such work it is better to use the usual covering of charcoal. Whenever the bath mixture is used, whether in a case hardening bath, heating bath, or lead pot cover, it is necessary to give the work a final treatment in a hot solution of soda ash.

On the subject of cyanamide case hardening we may add that we consider that its worth as a case hardener is well proven by five years of successful use on a wide variety of work. All that is necessary is for the user to become familiar with a few simple details and points in which the process differs from the cyanide process. When these are attended to it will be found that the case obtained is fully as hard and deep as can be obtained by any other liquid process, while the advantages are a materially lower cost and an absolute freedom from poisonous and irritating gases, with consequent comfort and safety of all who must work in the shop in which the case hardening is done.

TENSILE PROPERTIES OF SOME STRUCTURAL ALLOY STEELS AT HIGH TEMPERATURES

By H. J. French

IN THE attempted production of ammonia in the United States by the Haber process[1] gradual elongation and ultimately fracture of bolts in converter chamber heads has introduced serious operating difficulties. Under a mean temperature of 550 degrees Cent. to which heads, nuts and bolts were subjected the elongation of the latter was such as to require tightening of the nuts almost daily. The use of some of the more commonly employed structural alloy steels did not remove this difficulty and a search of the literature revealed little exact information on which a comparison of the high temperature tensile properties of various alloy steels could be based.

In view of the fact that an investigation of the resistance to corrosion by ammonia of various ferrous and nonferrous alloys was in progress in connection with redesign of operating equipment by the ordnance department, the Bureau of Standards was requested to undertake determination of the tensile properties of a number of structural alloy steels throughout the temperature range 20 to 550 degrees Cent. (70 to 1020 degrees Fahr.) From the combined results of investigation of resistance to corrosion of various metals and the tensile properties of steels at high temperatures, it was hoped that selection of a suitable alloy for withstanding required stresses could be made and if this proved unsatisfactory as regards resistance to attack by the gases encountered at least a more suitable metal lining for the converters could be installed.

The original plan of procedure included tests of a plain carbon steel and a number of structural alloy steels most of which were of acknowledged industrial importance. However, because of the desire to keep variations in carbon content to a minimum, difficulty was encountered in obtaining some of the alloys, notably carbon-manganese and chromium-molybdenum steels, of the exact compositions desired so that this report comprises only tests of four steels.

It is further restricted to tests of these alloys in a normalized condition as data so obtained form a basis of comparison with tests of samples first subjected to quenching and tempering. The high operating temperatures attained, which reach about 650 degrees Cent. (1200 degrees Fahr.) limit the tempering subsequent to hardening to relatively high temperatures while the large dimensions of the converter heads and some of the other parts of the equipment subjected to high temperatures, which would introduce difficulties in quenching, make the use of a forged or normalized steel highly desirable.

Shortly after completion of the tests about to be described, tensile properties at high temperatures of a number of carbon and alloy steels subjected to varying thermal treatments were reported by MacPherran[2] and in discussion of this paper by Spooner considerable additional data were presented. However, the work of MacPherran and Spooner was confined, in so far as the elastic properties are concerned, to determina-

1. R. S. Tour: "The Direct Synthetic Ammonia Process," Journ. Ind. and Eng. Chemistry, 12, No. 9, September, 1920, p. 844.
2. R. S. MacPherran: "Comparative Tests of Steels at High Temperatures," Proc. Amer. Soc. for Test. Mats., 1921.

A paper presented by title at the Indianapolis Convention. The author, H. J. French, is physicist, Bureau of Standards, Washington.

tion of yield point whereas the tests carried out by the present author include determinations of the limit of proportionality, and strength at fracture and the interpretation of these data is somewhat different from that given by either of the authors mentioned.

As already indicated, there was until quite recently a scarcity of accurate data on the high temperature tensile properties of various structural alloy steels. This is still the case as regards the effect of temperature on the limit of proportionality, of importance in design of engineering equipment, and in addition there is some disagreement between results reported by different investigators for similar alloys. Bregowsky and Spring[3] determined yield point, tensile strength, elongation and reduction of area from 20 to 550 degrees Cent. (70 to 1020 degrees Fahr.) for rolled 30 per cent nickel steel.

In 1913 Schulz[4] reviewed available data relating to the high temperature properties of turbine materials but the information presented for alloy steels was in large part for those containing varying proportions of nickel.

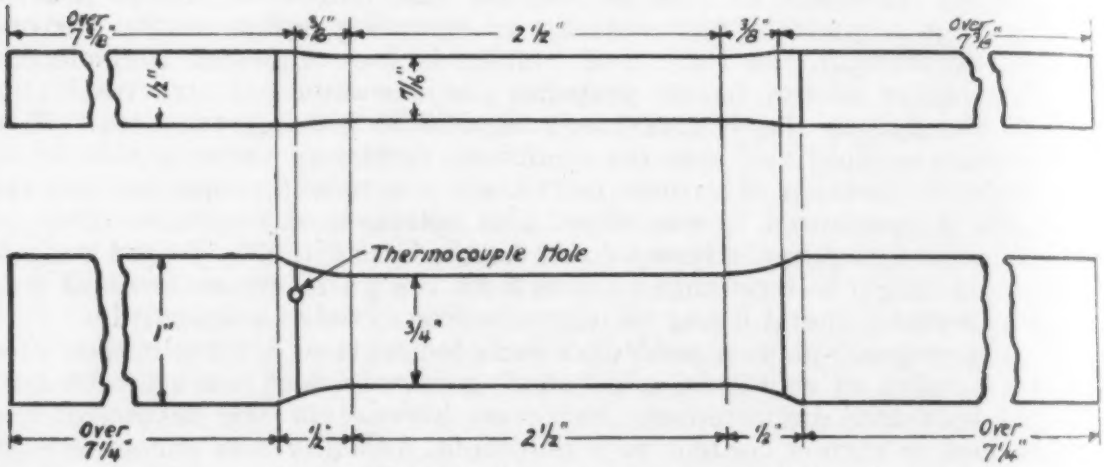


Fig. 1—Form and dimensions of test specimen used

Guillet[5] reported, among several special alloys for use at high temperatures, a steel containing nickel, chromium and tungsten which showed exceptionally high strength at 750 to 800 degrees Cent. (1380 to 1470 degrees Fahr.)

A comprehensive analysis of the effects of high temperatures on hardness, tensile and impact properties, freedom from warpage, etc., of steels containing 3 per cent nickel and various proportions of chromium, high speed steels and various chromium and chromium-cobalt steels was recently prepared by Gabriel[6]. As regards high tensile strength at elevated temperatures these steels were considered of value in the following order:

1. High tungsten

3. I. M. Bregowsky and L. W. Spring: "The Effect of High Temperature on the Physical Properties of Some Alloys, Proc. Inst. Assoc. for Test. Mats., VI Congress, 1912, VIII.

4. Schulz: "Neuere Versuche und Erfahringen mit Turbinenschau felmaterial fur hohe Temperaturen," Die Turbine, 9 (1913), p. 243.

5. L. Guillet: "Alloys Having Remarkable Properties at Very High or Very Low Temperatures," Rev. Met. 11 (1914), p. 969.

6. G. Gabriel: "Comparative Values of Motor Valve Steels." Iron Age, 106 (1920), p. 1455.

2. High chromium, high carbon
3. High chromium, low carbon
4. 3 per cent nickel and nickel-chromium.

In the selection of steels for valves the author recommended the different type alloys as follows:

1. A tungsten steel

Table I

Alloy Steels Tested at High Temperatures

By Mac Pherran*

Type composition, per cent					
Carbon	Manganese	Nickel	Chromium	Vanadium	Condition in which steel was tested
0.21	....	3.25	....	....	Annealed at 802 degrees Cent. (1475 degrees Fahr.)
0.25	....	33.9	....	....	Annealed at 802 degrees Cent. (1475 degrees Fahr.)
0.34	....	2.38	0.38	....	816 degrees Cent. (1500 degrees Fahr.) water. 705 degrees Cent. (1300 degrees Fahr.)
0.53	....	20.78	7.42	....	As rolled.
0.39	....	....	0.83	0.17	857 degrees Cent. (1575 degrees Fahr.) water. 732 degrees Cent. (1350 degrees Fahr.)
0.69	....	....	3.36	....	843 degrees Cent. (1550 degrees Fahr.) water. 705 degrees Cent. (1300 degrees Fahr.)
0.72	0.92	....	....	....	Annealed at 802 degrees Cent. (1475 degrees Fahr.)
0.82	....	....	0.91	0.18	816 degrees Cent. (1500 degrees Fahr.) water. 705 degrees Cent. (1500 degrees Fahr.)

*American Society for Testing Materials, 1921.

Table II

Alloy Steels Tested at High Temperatures

By A. P. Spooner*

Type composition, per cent						
Carbon	Nickel	Chromium	Vanadium	Molybdenum	Tungsten	Condition in which steel was tested
0.10	....	....	....	....	....	Normalized 870 degrees Cent. (1600 degrees Fahr.)
0.45	....	....	....	....	....	Normalized 870 degrees Cent. (1600 degrees Fahr.)
0.33	3.5	....	....	....	....	Normalized 870 degrees Cent. (1600 degrees Fahr.)
0.38	2.0	1.0	....	....	....	Normalized 870 degrees Cent. (1600 degrees Fahr.)
0.37	....	1.0	0.20	....	....	Normalized 870 degrees Cent. (1600 degrees Fahr.)
0.47	....	1.0	....	0.35	....	Normalized 870 degrees Cent. (1600 degrees Fahr.)
1.10	....	0.50	0.20	....	....	Annealed 740 degrees Cent. (1360 degrees Fahr.)
0.48	....	1.3	0.20	....	....	Annealed 730 degrees Cent. (1350 degrees Fahr.)
0.25	....	14.0	....	....	....	Annealed 790 degrees Cent. (1450 degrees Fahr.)
0.66	....	3.2	0.70	....	15.9	Annealed 905 degrees Cent. (1660 degrees Fahr.)
0.20	....	31.0	....	....	....	Annealed 760 degrees Cent. (1400 degrees Fahr.)

*Proceedings American Society for Testing Materials, 1921.

Table III

Composition and Heat Treatment of Steels Tested

Steel	Composition, per cent								Heat treatment* Degrees Cent.
	Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium	Vanadium	
A	0.38	0.56	0.014	0.013	0.14	....	....	....	850
B	0.37	0.67	0.021	0.010	0.20	3.43	....	....	800
C	0.39	0.59	0.019	0.009	0.23	3.05	0.93	....	850
D	0.37	0.74	0.020	0.023	0.21	....	1.04	0.17	850

*Specimens heated for 30 minutes at temperature designated and cooled in still air.

2. A steel high in chromium
3. A nickel steel.

MacPherran[7] recently reported tensile tests from 20 to about 650 degrees Cent. (70 to 1200 degrees Fahr.) for a variety of alloy steels under different heat treatments as shown in Table I. In discussion of this paper, A. P. Spooner presented a large number of tests at temperatures up to about 870 degrees Cent. (1600 degrees Fahr.) for the different steels listed in Table II and in general confirmed the work of MacPher-

7. See note 2.

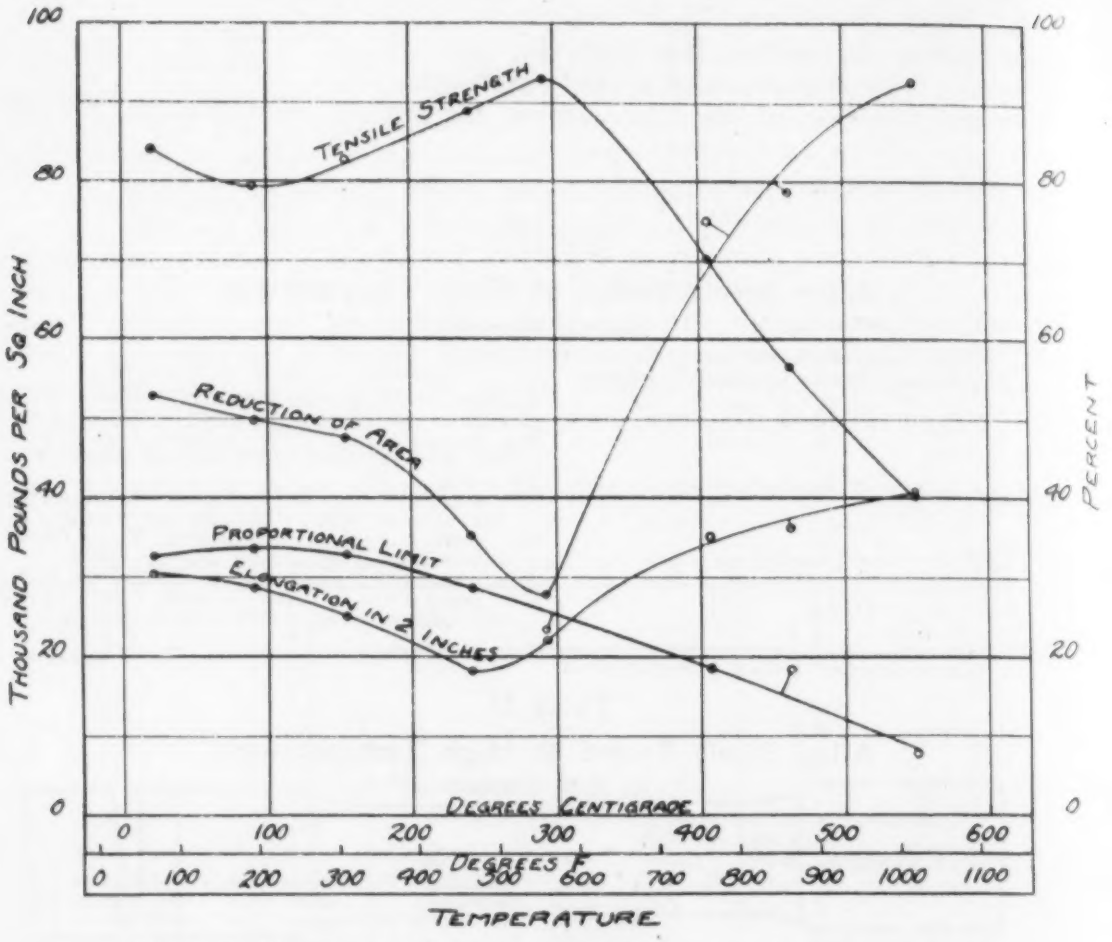


Fig. 2—Tensile properties of 0.38 per cent carbon steel at elevated temperatures

ran in most cases where direct comparisons between results were made possible.

These data, while the most recently presented, are together the most comprehensive compilation of tests so far recorded for the modern types of structural alloy steels but consist of determinations of tensile strength, elongation, reduction of area and, in part of the temperature ranges given, values for yield point.

The four steels tested were made by the electric furnace process at the plant of the Halcomb Steel Co., Syracuse, N. Y., and supplied in the form of 1 by ½-inch hot rolled bars of the compositions shown in Table III. After cutting into desired lengths for test specimens, the bars were normalized by heating to 800 or 850 degrees Cent. and cooled in still air. They were then machined to the form and dimensions shown in Fig. 1.

All tests were made with the special apparatus devised by the author and in the manner previously described[8] in detail.

The results of tensile tests at various temperatures throughout the range 20 to 550 degrees Cent. (70 to 1020 degrees Fahr.) are given in Tables IV, V, VI and VII and represented graphically in Figs. 2 to 5 inclusive.

Maximum strength of the carbon, 3.5 per cent nickel and nickel-

8. Forthcoming Bureau Technologic Paper "Effect of Temperature Deformation and Rate of Loading on the Tensile Properties of Low Carbon Steel Below the Thermal Critical Range." Also H. J. French, "Tensile Properties of Boiler Plate at Elevated Temperatures," Mining and Metallurgy, 158 (1920), Section 15.

chromium steels occurs between about 240 and 300 degrees Cent. (465 and 565 degrees Fahr.) whereas the strength of the chromium-vanadium steel does not exceed its room temperature value within the temperature range under consideration. However, a rapid decrease in this factor is observed in all steels above about 300 degrees Cent. (565 degrees Fahr.)

At 550 degrees Cent. (1020 degrees Fahr.) the strength of the chromium-vanadium steel is very much greater than that of the other alloys and more than twice that of the carbon steel. It has likewise decreased the least in strength from its room temperature value as shown in Table VIII. However, at all temperatures below about 475 degrees Cent. (885 degrees Fahr.) the strength of the nickel chromium steel is greater than that of the chromium-vanadium.

The proportional limits of the carbon, 3.5 per cent nickel and nickel-chromium steels increase with first rise in temperature and reach maximum values in the neighborhood of 150 degrees Cent. (300 degrees Fahr.) whereas that of the chromium-vanadium steel is greatest at room temperature and, following a marked decrease, again increases perceptibly between about 150 to 250 degrees Cent. (300 to 480 degrees Fahr.) before final decrease occurs. While the maximum value of the limit of propor-

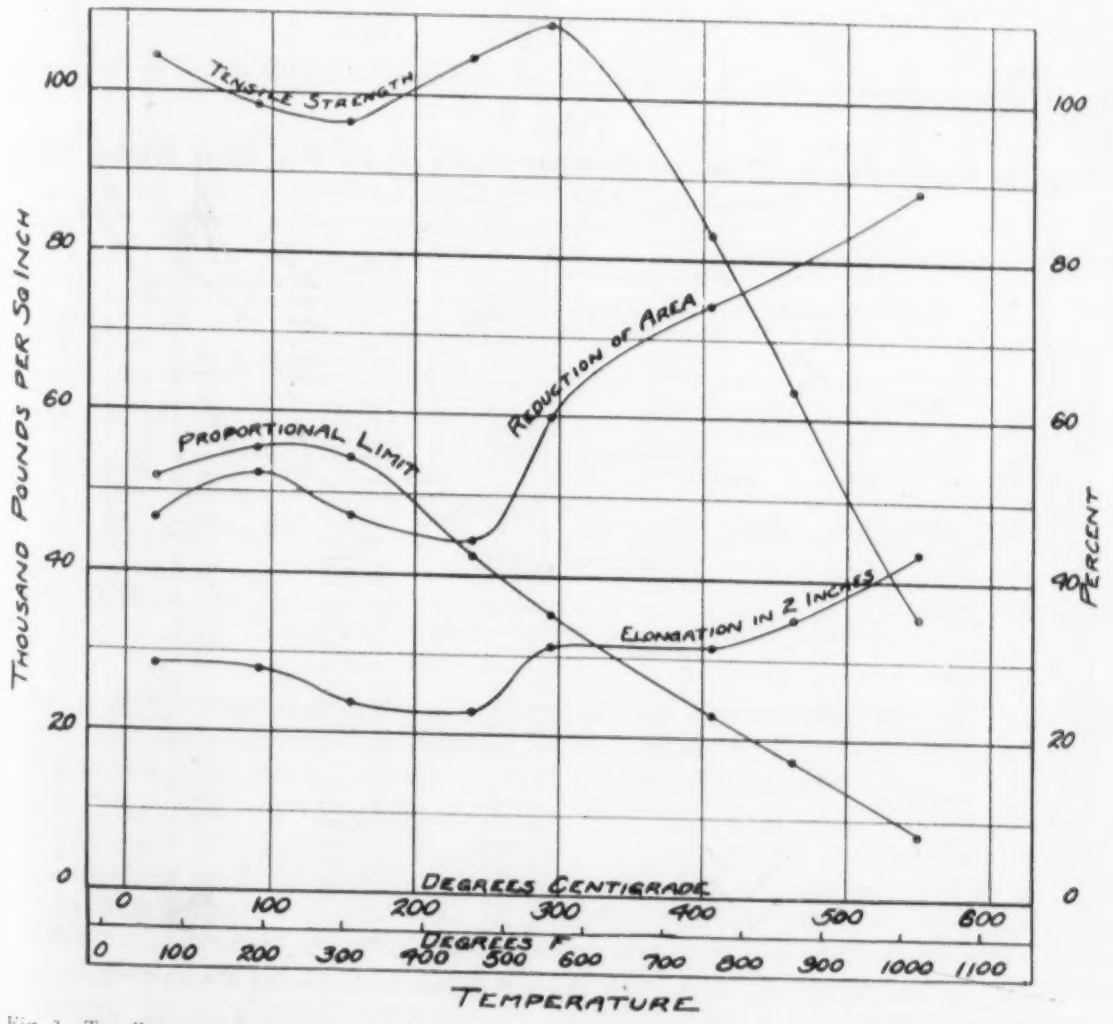


Fig. 3—Tensile properties at elevated temperatures of 3.5 per cent nickel steel containing 0.37 per cent carbon

Table IV

Tensile Properties of 0.38 Per Cent Carbon Steel at High Temperatures

Chemical composition, per cent			Carbon 0.38	Manganese 0.56	Phosphorus 0.014	Sulphur 0.013	Silicon 0.14
No.	Temperature of test—Degrees Cent.	Degrees Fahr	Proportional limit, Pounds per square inch	Tensile strength, Pounds per square inch	Breaking strength*, Pounds per square inch	Elongation in 2 inches Per cent	Reduction of area Per cent
A-1	Room		34,900	85,200	.....	27.5	52.3
A-2	Temperature		30,500	83,200	.....	33.5	53.3
Av.	21	70	32,700	84,200	.....	30.5	52.8
A-6	92	...	34,000	79,400	.....	28.0	47.6
A-9	92	...	33,700	79,500	.....	29.5	52.2
Av.	92	198	33,850	79,450	.....	28.8	49.9
A-10	155	...	33,250	85,500	140,000	24.5	47.2
A-13	155	...	32,750	80,200	137,000	26.0	48.3
Av.	155	311	33,000	82,850	138,500	25.2	47.8
A-12	241	...	27,500	87,500	129,000	19.0	37.0
A-17	241	...	.....	90,400	127,400	18.0	32.7
A-18	241	...	30,000	88,900	129,700	17.5	36.9
Av.	241	466	28,750	88,950	128,700	18.2	35.5
A-8	292	...	26,000	91,500	.....	24.0	28.6
A-11	294	...	24,500	93,500	116,700	20.0	27.5
A-19	294	...	20,000	94,000	.....	....	....
Av.	293	559	23,500	93,000	.....	22.0	28.0
A-7	407	...	18,500	68,000	137,700	36.5	76.2
A-15	407	...	18,500	72,500	145,800	34.0	73.8
Av.	407	765	18,500	70,250	141,750	35.2	75.0
A-3	463	...	21,400	57,300	.....	35.5	78.1
A-16	463	...	15,300	56,000	123,700	37.0	79.2
Av.	463	865	18,350	56,650	.....	36.2	78.6
A-21	550	...	9,500	41,700	133,200	38.0	93.0
A-22	550	...	6,000	38,150	100,300	43.0	92.5
Av.	550	1022	7,750	39,950	116,750	40.5	92.7

*Breaking strength is taken as the load observed at fracture in pounds divided by the reduced area in square inches.

Table V

Tensile Properties at Elevated Temperatures of 3.5 Per Cent Nickel Steel Containing 0.37 Per Cent Carbon

Chemical composition, per cent			Carbon 0.37	Manganese 0.67	Phosphorus 0.021	Sulphur 0.010	Silicon 0.20	Nickel 3.43
No.	Temperature of test—Degrees Cent.	Degrees Fahr	Proportional limit, Pounds per square inch	Tensile strength, Pounds per square inch	Breaking strength*, Pounds per square inch		Elongation in 2 inches Per cent	Reduction of area Per cent
B-16	...	...	47,000	105,150	172,500		30.5	50.6
B-17	Room		56,000	104,900	164,000		27.5	46.7
B-2	Temperature		.....	103,600	152,000		27.5	39.9
B-4	...	...	52,500	103,400	170,800		28.0	49.7
Av.	21	70	51,850	104,250	164,800		28.4	46.7
B-21	92	...	53,000	97,600	169,200		28.5	54.1
B-22	92	...	58,000	97,800	170,300		29.0	52.3
B-1	92	...	.....	99,600	169,500		26.0	51.3
B-3	92	...	.....	99,300	172,300		28.0	52.4
Av.	92	198	55,500	98,600	170,300		27.9	52.5
B-6	155	...	52,500	97,100	170,800		22.0	43.2
B-12	155	...	56,000	96,200	159,700		24.5	47.3
B-19	155	...	55,000	98,300	169,300		25.0	49.4
B-5	155	...	.....	95,000	161,300		23.5	48.5
Av.	155	311	54,500	96,650	165,300		23.8	47.1
B-18	241	...	42,500	104,600	181,200		25.0	51.5
B-7	241	...	.....	106,200	163,600		22.0	40.6
B-8	241	...	42,500	103,500	154,300		21.5	40.9
Av.	241	466	42,500	104,750	166,350		22.8	44.3
B-10	294	...	34,000	109,500	194,400		31.0	60.2
B-9	294	...	36,500	108,900	194,800		32.0	59.7
Av.	294	561	35,250	109,200	194,600		31.5	60.5
B-15	407	...	21,500	83,000	152,600		31.5	74.4
B-13	407	...	24,000	83,250	169,700		31.5	74.5
Av.	407	765	22,750	83,150	161,150		31.5	74.5
B-14	463	...	16,000	63,900	126,400		35.0	79.6
B-11	463	...	18,500	63,500	127,900		35.0	79.7
Av.	463	865	17,250	63,700	127,150		35.0	79.7
B-24	550	...	7,500	37,400	79,000		42.5	88.3
B-25	550	...	9,000	33,300	76,300		44.5	89.5
Av.	550	1022	8,250	35,350	77,650		43.5	88.9

*Breaking strength is taken as the load observed at fracture in pounds divided by the reduced area in square inches.

tionality of the nickel-chromium steel occurs at about 150 degrees Cent. (300 degrees Fahr.) and is followed by a material decrease, a second rise in value is observed at about 300 degrees Cent. (570 degrees Fahr.) so that this factor is maintained above its room temperature value until temperatures above about 370 degrees Cent. (700 degrees Fahr.) are reached.

The limit of proportionality of the chromium-vanadium steel at 550 degrees Cent. (1020 degrees Fahr.) has decreased proportionally more

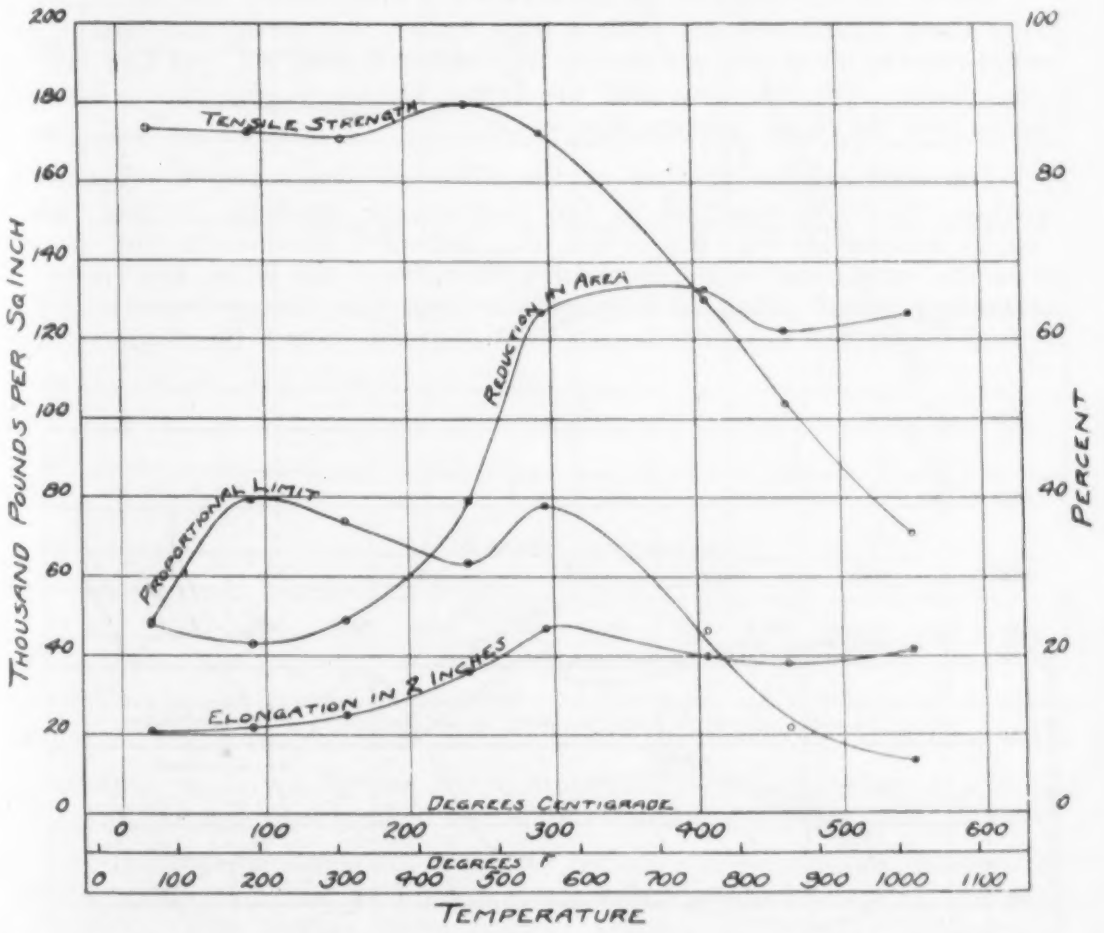


Fig. 4—Tensile properties at elevated temperatures of nickel-chromium steel of the type 3 per cent nickel, 1 per cent chromium and 0.4 per cent carbon

than either the carbon or nickel-chromium steels as shown in Table IX, but its value at the high temperature indicated is greater than either of the latter and more than twice that of the carbon steel.

The effect of temperature is greater upon the values of reduction of area than elongation. In general the inflections in the temperature-elongation and temperature-reduction of area curves shown in Figs. 2, 3, 4 and 5 are so varied that no attempt will be made to describe them. However, several generalizations may be made. The carbon and 3.5 per cent nickel steels behave similarly in that rise in temperature is accompanied by a general decrease in ductility which is followed above the range 200 to 300 degrees Cent. (390 to 565 degrees Fahr.) by an in-

crease until at 550 degrees Cent. (1020 degrees Fahr.) values of elongation and reduction of area are greater than those observed at room temperature.

Elongation of the chromium-vanadium steel is about the same at 550 degrees Cent. (1020 degrees Fahr.) as at room temperature and does not show any very great changes throughout this temperature range whereas elongation of the nickel-chromium steel increases to a maximum at about 295 degrees Cent. (565 degrees Fahr.) or blue heat.

While the carbon and nickel steels are much more ductile at 550 degrees Cent. (1020 degrees Fahr.) than either the chromium-vanadium or nickel-chromium steels, as shown in Tables X and XI, yet the last two alloys have high ductility and the latter shows by far the greatest increase over its room temperature value.

The strength at fracture of the different steels tested, obtained by dividing the load observed at the moment of breaking by the reduced area, is shown in Fig. 6. While the data are incomplete and in some cases the variations in duplicate determinations are wide, the results are interesting when taken in conjunction with the changes previously described for at 550 degrees Cent. (1020 degrees Fahr.) the highest break-

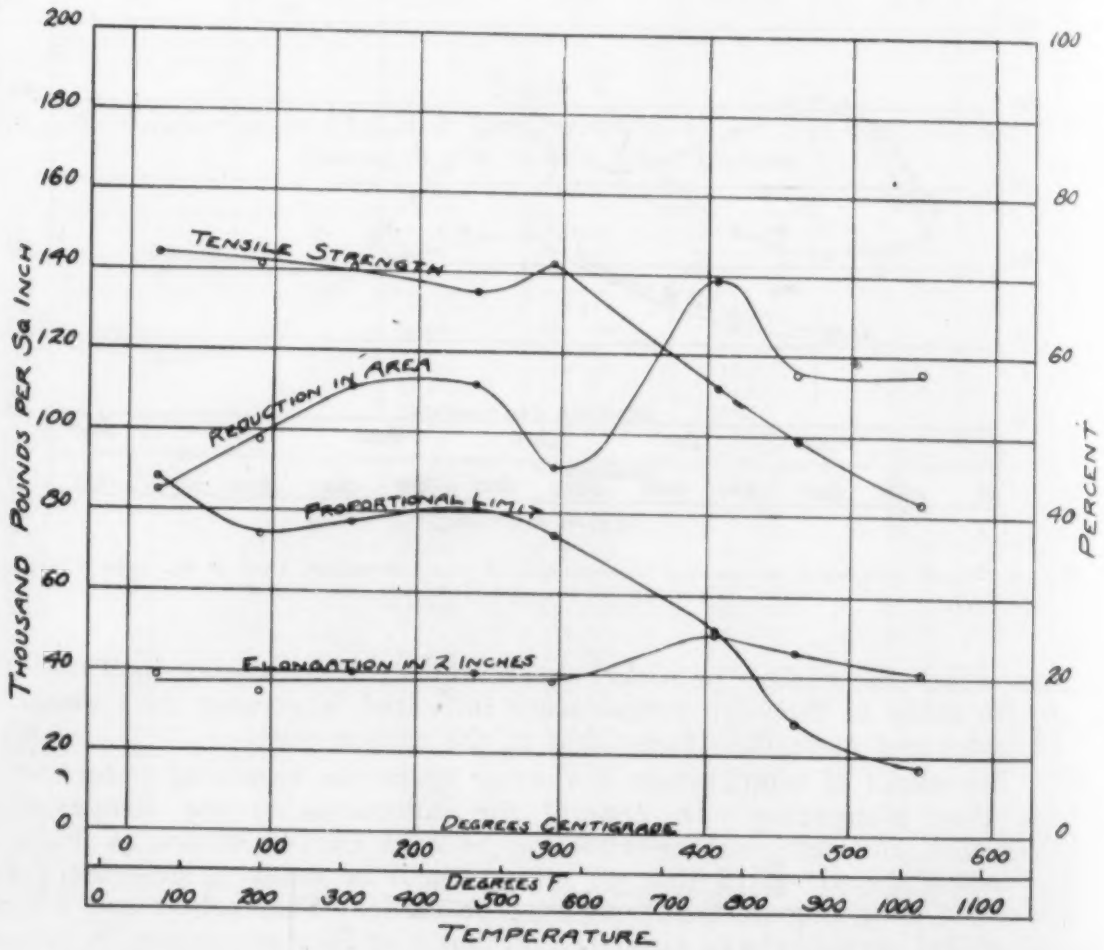


Fig. 5—Tensile properties at elevated temperatures of chromium-vanadium steel of the type 1 per cent chromium, 0.2 per cent vanadium and 0.37 per cent carbon

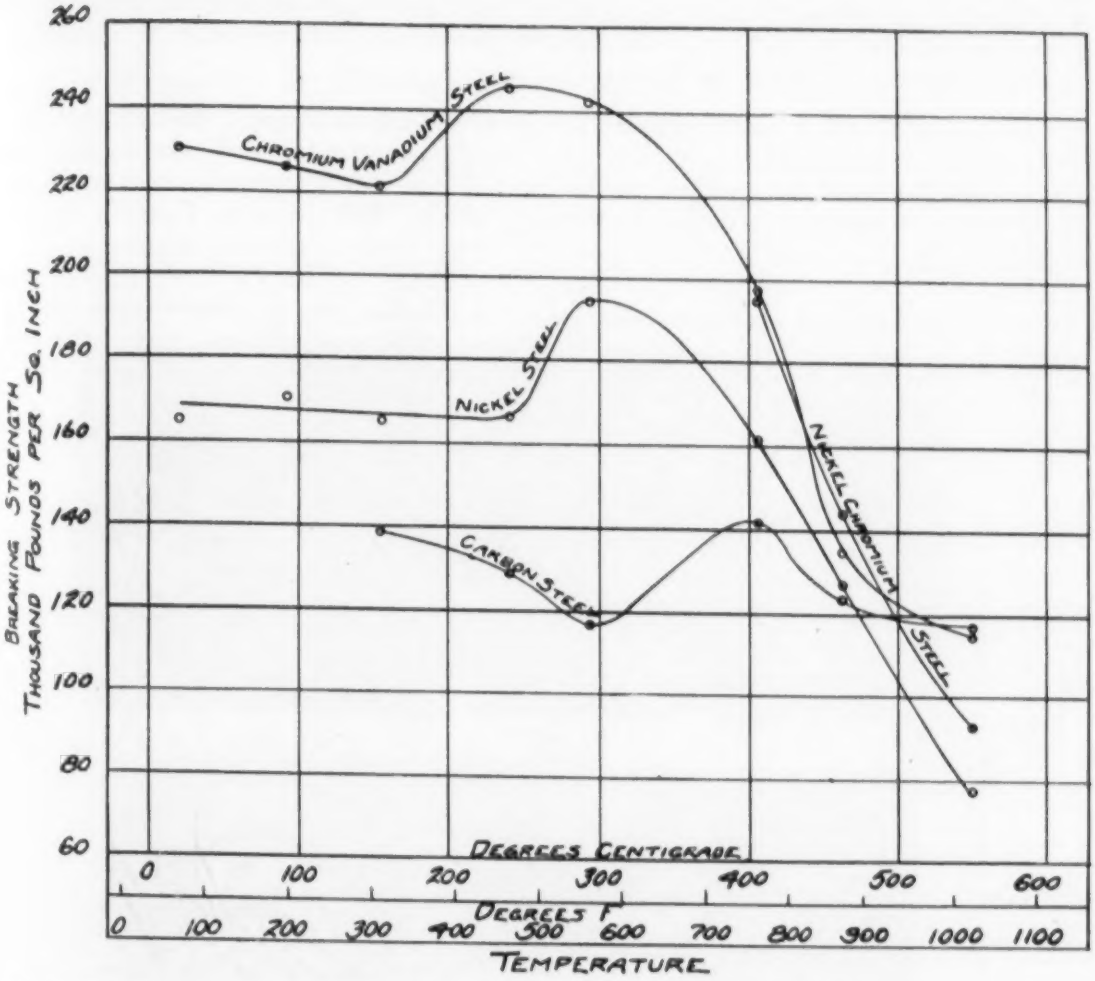


Fig. 6—Breaking strength at elevated temperatures of carbon, nickel, nickel-chromium and chromium-vanadium steels. Compositions of these steels are shown in Table III

ing strength is shown by the chromium-vanadium and carbon steels and the lowest value is observed in the alloy containing 3.5 per cent nickel.

The fracture of steels subjected to tensile stress at room temperature is transcrystalline while at high temperatures it takes place at the grain boundaries. The change from transcrystalline to intercrystalline fractures will occur beginning at temperatures somewhat above that of equal cohesion of the amorphous and crystalline phases, but the temperatures at which these fractures first appear in a given alloy depends upon the rate of loading[9]. The faster the load is applied, the higher is the temperature required to produce intercrystalline breaks.

Jeffries states that in most metals the equicohesive temperature occurs at about 0.35 to 0.45 of the absolute melting point so that for steels the change from fractures across the grains to those along the crystal boundaries should on slow loading first appear in the neighborhood of 550 degrees Cent. (1050 degrees Fahr.)

This temperature is approximately the highest at which tensile tests were made and as these were likewise considered of particular interest

9. Zay Jeffries: "Effect of Temperature, Deformation, and Grain Size on the Mechanical Properties of Metals." Trans. A. I. M. E., 60 (1919), p. 474.

from the standpoint of operation in the Haber process, specimens of the several steels tested were examined under the microscope to determine the character of the fractures.

Typical microphotographs are reproduced in Figs. 7 and 8 and while no general statements can be made with certainty, they show the tendency of the fracture in the carbon and 3.5 per cent nickel steels to follow the grain boundaries when broken at about 550 degrees Cent. (1020 degrees Fahr.)

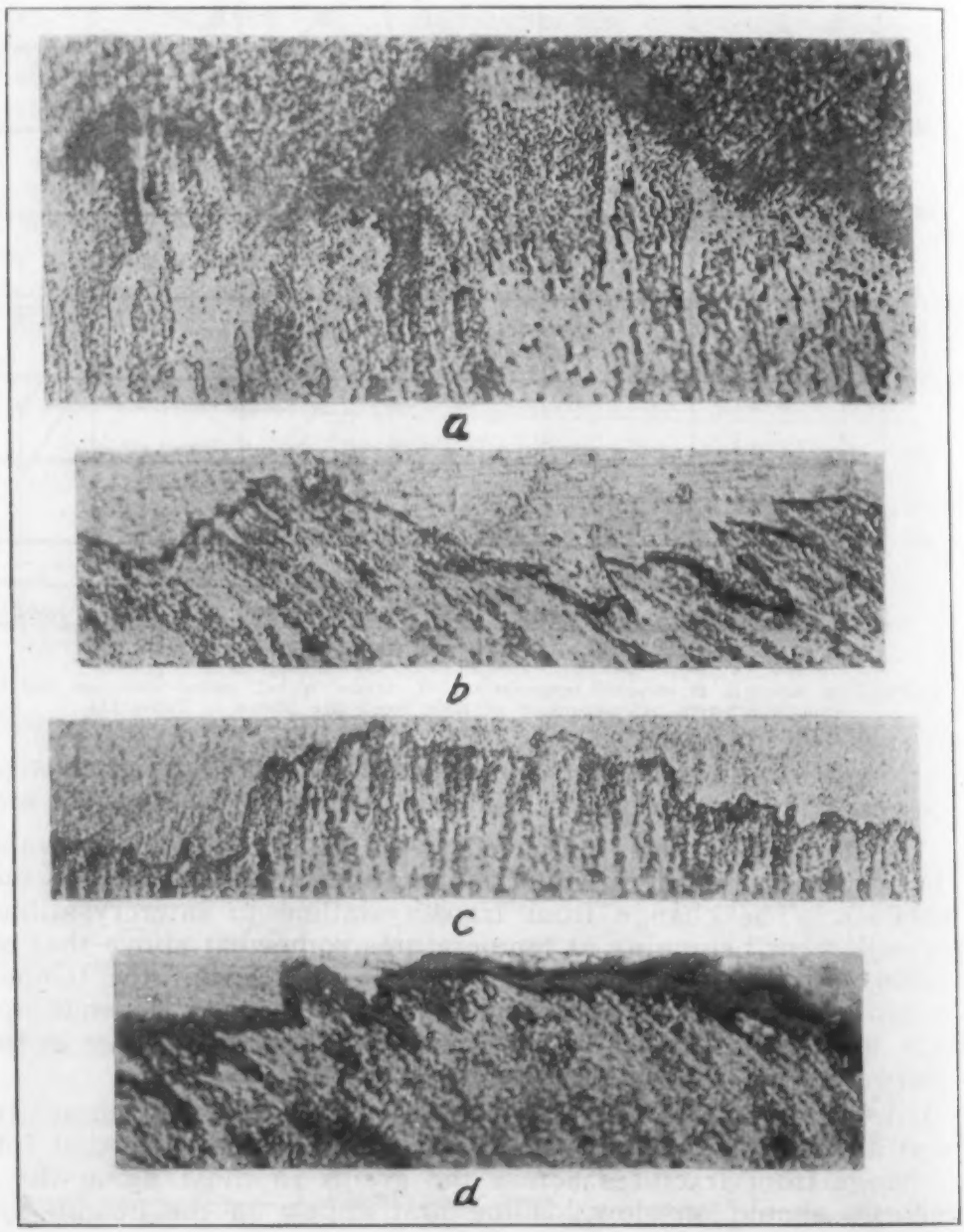


Fig. 7—Photomicrographs of fractures of carbon and 3.5 per cent nickel steels broken in tension at high temperatures. *a* is specimen A-16, broken at 463 degrees Cent. X 500. *b* is specimen A-22, broken at 550 degrees Cent. X 500. *c* is specimen B-11, broken at 463 degrees Cent. X 500. *d* is specimen B-24, broken at 550 degrees Cent. X 1000. All specimens etched with 5 per cent picric acid in alcohol

Table VI

Tensile Properties at Elevated Temperatures of Nickel-Chromium Steel of Type 3 Per Cent Nickel, 1 Per Cent Chromium, 0.4 Per Cent Carbon

	Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium
Chemical composition, per cent	0.39	0.59	0.019	0.009	0.23	3.05	0.93

No.	Temperature of test, Degrees Cent.	Degrees Fahr	Proportional limit, Pounds per square inch	Tensile strength, Pounds per square inch	Breaking strength*, Pounds per square inch	Elongation in 2 inches Per cent	Reduction of area Per cent
C-14	Room		58,500	175,000	213,700	10.0	22.9
C-15	Temperature		58,500	171,800	207,000	11.0	25.2
Av.	21	70	58,500	173,400	210,350	10.5	24.0
C-2	92	...	84,700	175,000	.....	11.0	20.3
C-3	92	...	74,000	170,000	.....	11.0	23.1
Av.	92	198	79,350	172,500	.....	11.0	21.7
C-6	155	...	75,000	175,200	.....	12.5	23.2
C-7	155	...	72,500	166,000	.....	12.5	26.2
Av.	155	311	73,750	170,600	.....	12.5	24.7
C-4	241	...	63,500	181,300	.....	18.0	39.6
C-5	241	...	62,500	178,000	.....	....	....
Av.	241	466	63,000	179,650	.....	18.0	39.6
C-8	294	...	75,000	174,000	.....	23.5	62.4
C-9	294	...	80,000	171,000	.....	23.5	63.8
Av.	294	561	77,500	172,500	.....	23.5	63.1
C-10	407	...	43,000	127,600	181,200	20.0	66.5
C-11	407	...	49,000	132,200	209,000	20.0	65.4
Av.	407	765	46,000	129,900	195,100	20.0	66.0
C-12	463	...	22,000	105,000	137,700	19.0	59.9
C-13	463	...	21,500	102,500	150,300	19.0	62.0
Av.	463	865	21,750	103,750	144,000	19.0	61.0
C-16	550	...	12,000	72,100	90,000	19.0	59.0
C-17	550	...	15,000	69,500	95,750	22.5	67.3
Av.	550	1022	13,500	70,800	92,850	20.8	63.2

*Breaking strength is taken as the load observed at fracture in pounds divided by the reduced area in square inches.

Table VII

Tensile Properties at Elevated Temperatures of Chromium-Vanadium Steel of Type 1 Per Cent Chromium, 0.2 Per Cent Vanadium, 0.37 Per Cent Carbon

	Carbon	Manganese	Phosphorus	Sulphur	Silicon	Chromium	Vanadium
Chemical composition, per cent	0.37	0.74	0.020	0.013	0.21	1.04	0.17

No.	Temperature of test, Degrees Cent.	Degrees Fahr	Proportional limit, Pounds per square inch	Tensile strength, Pounds per square inch	Breaking strength*, Pounds per square inch	Elongation in 2 inches Per cent	Reduction of area Per cent
D-1	Room		88,000	141,600	236,000	20.0	55.5
D-16	Temperature		88,000	147,000	224,500	19.0	49.4
Av	21	70	88,000	144,300	230,250	19.5	42.5
D-3	92	...	81,000	150,800	229,400	17.5	48.4
D-4	92	...	70,000	135,100	224,300	18.0	51.7
D-15	92	...	73,000	139,500	224,100	17.5	46.2
Av.	92	198	74,650	141,800	225,950	17.7	48.8
D-7	155	...	76,000	136,200	240,000	20.0	55.7
D-8	155	...	79,000	146,500	203,000	....	....
Av.	155	311	77,500	141,350	221,500	20.0	55.7
D-5	241	...	81,000	133,600	252,300	21.0	58.6
D-6	241	...	80,000	137,200	238,700	19.0	53.3
Av.	241	466	80,500	135,400	245,500	20.0	56.0
D-9	294	...	76,000	145,500	223,400	19.0	45.8
D-10	294	...	73,000	139,000	261,300	.....	....
Av.	294	561	74,500	142,250	242,350	19.0	45.8
D-11	407	...	50,000	108,000	182,300	25.0	67.7
D-12	407	...	51,500	115,200	213,000	25.0	71.2
Av.	407	765	50,750	111,600	197,500	25.0	69.5
D-13	463	...	27,000	97,500	122,500	23.5	52.9
D-14	463	...	29,000	101,000	147,300	22.5	62.4
Av.	463	865	28,000	99,250	134,900	23.0	57.7
D-18	550	...	16,500	82,600	119,800	22.0	61.7
D-19	550	...	17,500	84,000	111,000	19.0	54.4
Av.	550	1022	17,000	83,300	114,900	20.5	58.0

*Breaking strength is taken as the load observed at fracture in pounds divided by the reduced area in square inches.

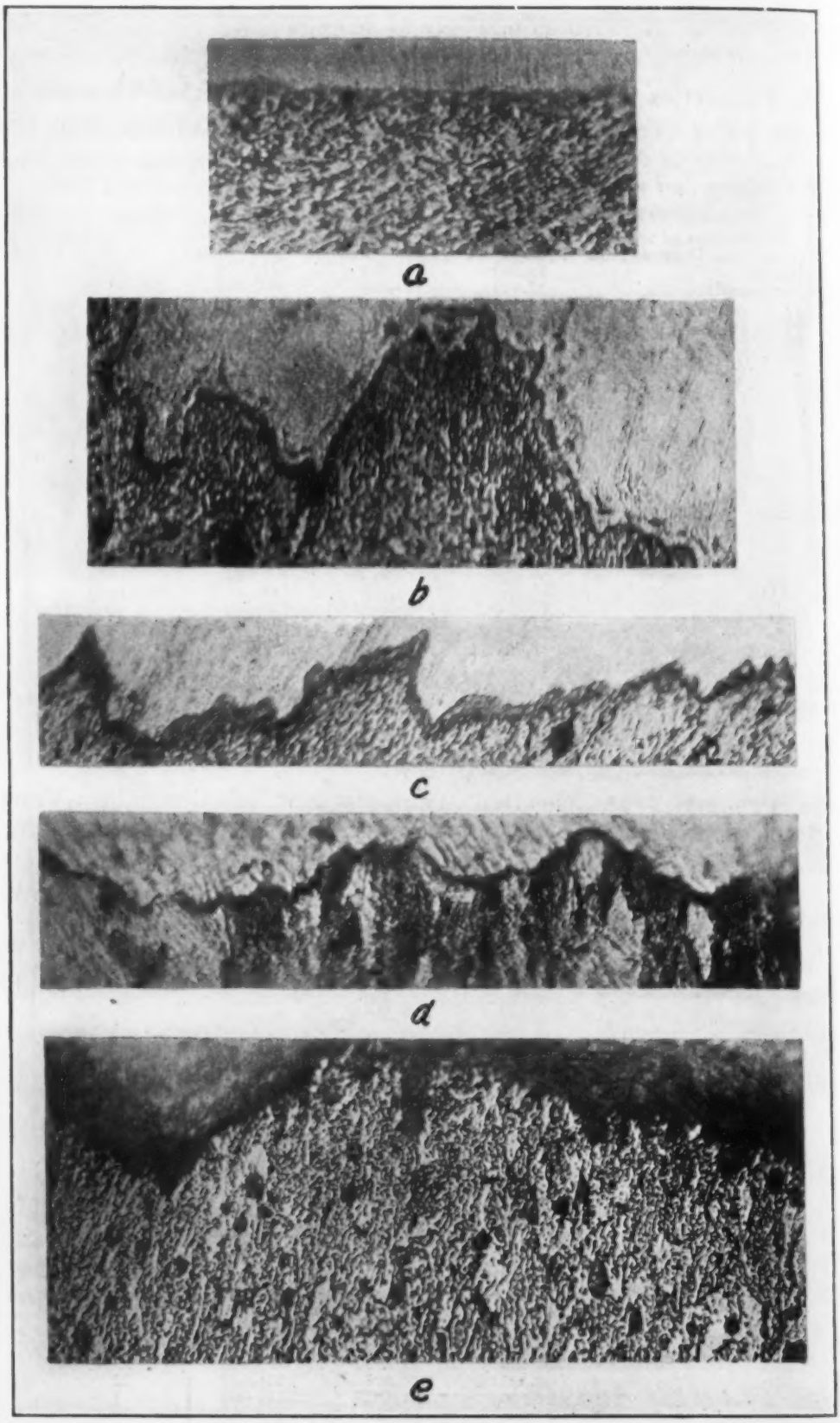


Fig. 8—Photomicrographs of fractures of nickel-chromium and chromium-vanadium steels broken in tension at high temperatures. *a* is specimen C-8, broken at 294 degrees Cent. X 1000. *b* is specimen C-13, broken at 463 degrees Cent. X 500. *c* is specimen C-16, broken at 550 degrees Cent. X 500. *d* is specimen D-14, broken at 463 degrees Cent. X 1000. *e* is specimen D-18, broken at 550 degrees Cent. X 500. *a*, *d* and *e* are etched with 5 per cent picric acid in alcohol; *b* and *c* with 2 per cent nitric acid in alcohol

The outstanding feature of the nickel-chromium steel is the fineness of the structure making it difficult to determine the character of the break, while in the case of the chromium-vanadium steel the fractures appear more nearly intercrystalline even at the highest temperatures under investigation.

The following points appear to deserve emphasis in connection with the tests previously described:

1. Of the four steels tested in normalized condition it appears that the two alloys containing chromium show greater resistance to weakening by increase in temperature to about 550 degrees Cent. (1020 degrees Fahr.) than either the plain carbon or 3.5 per cent nickel steels and at this highest temperature, the chromium-vanadium steel is to be preferred from the standpoint of high tensile strength and limit of proportionality.

Table VIII

Comparison of Tensile Strengths of Carbon and Alloy Steels at Room Temperature and 550 Degrees Cent.

Steel	Tensile strength at room temperature pound per square inch	At 550 degrees Cent. (1022 degrees Fahr.) Actual tensile strength pound per square inch	Decrease from room temperature value Per cent	Ratio of tensile strengths with carbon steel as unity
Carbon	84,200	39,950	52.5	1
Nickel	104,250	35,350	66.0	0.9
Nickel-chromium	173,400	70,800	59.1	1.8
Chromium-vanadium	144,300	83,300	42.4	2.1

Table IX

Comparison of Proportional Limits of Carbon and Alloy Steels at Room Temperature and 550 Degrees Cent.

Steel	Proportional limit at room temperature pound per square inch	At 550 degrees Cent. (1022 degrees Fahr.) Actual proportional limit pound per square inch	Decrease from room temperature value Per cent	Ratio of proportional limits with carbon steel as unity
Carbon	32,700	7,750	76.3	1
Nickel	51,850	8,250	84.2	1.1
Nickel-chromium	58,500	13,500	77.6	1.7
Chromium-vanadium	88,000	17,000	80.7	2.2

Table X

Comparison of Elongations of Carbon and Alloy Steels at Room Temperature and 550 Degrees Cent.

Steel	Elongation in 2 inches at room temperature Per cent	At 550 degrees Cent. (1022 degrees Fahr.) Actual elongation in 2 inches Per cent	Increase from room temperature value Per cent	Ratio of elongations with carbon steel as unity
Carbon	30.5	40.5	32.8	1
Nickel	28.4	43.5	51.4	1.1
Nickel-chromium	10.5	20.8	98.0	0.5
Chromium-vanadium	19.5	20.5	5.1	0.5

Table XI

Comparison of Reductions of Area of Carbon and Alloy Steels at Room Temperature and 550 Degrees Cent.

Steel	Reduction of area at room temperature Per cent	At 550 degrees Cent. (1022 degrees Fahr.) Actual reduction of area Per cent	Increase from room temperature value Per cent	Ratio of reductions of area with carbon steel as unity
Carbon	52.8	92.7	75.5	1
Nickel	46.7	88.9	90.3	1
Nickel-chromium	24.0	63.2	163.3	0.7
Chromium-vanadium	42.5	58.0	36.5	0.6

2. The carbon and 3.5 per cent nickel steels behave alike with rise in temperature and at about 550 degrees Cent. (1020 degrees Fahr.) the addition of the nickel appears to have a very small effect on the tensile properties of the carbon steel.

3. At 550 degrees Cent. (1020 degrees Fahr.) the strength and limit of proportionality of the chromium-vanadium steel is more than twice that of the carbon steel while the ductility of the former, as measured by elongation and reduction of area is about half that of the latter, though still quite high. However, at all temperatures below about 475 degrees Cent. (885 degrees Fahr.) the strength of the nickel-chromium steel is greater than that of the chromium-vanadium and both show higher strength values throughout the range 20 to 550 degrees Cent. (70 to 1020 degrees Fahr.) than the carbon or 3.5 per cent nickel steels.

4. While no general statements regarding types of fractures can be made with certainty the tendency of carbon and 3.5 per cent nickel steels at about 550 degrees Cent. (1020 degrees Fahr.) is to follow the grain boundaries while at the same temperature the fractures of the chromium-vanadium steel appear largely transcrystalline.

In conclusion, acknowledgment is made to C. E. Lermond, mechanical draftsman, Ordnance Department, and T. E. Hamill, laboratory apprentice, Bureau of Standards, for carrying out the greater part of the routine tensile tests reported in this paper.

A UNIVERSITY COURSE IN METALLURGICAL ENGINEERING

By W. P. Wood

IN PREPARING the curriculum herein discussed the writer has had in mind the preparation of students not so much for the mining and mill end of metallurgy as for those industries which are concerned with the final shaping and preparing of the metal for use. A typical example of this type of industry is the manufacture of automobiles with all its allied interests. Such plants receive the metal as raw material from the mill and after fashioning it and probably heat treating it, assembled it in its proper position in the product which they are turning out. They are interested in the actual manufacture of the raw material only in so far as it affects the operations which they subsequently carry out upon the metal.

The writer has been influenced personally in laying out of this course by close proximity to these types of industry, and this leads to another point that may serve as additional support for a course which emphasizes the phase of metallurgy which has already been mentioned as having influenced the nature of this curriculum. It is felt that any institution which gives instruction in engineering should place emphasis upon the phases of industry which are of most importance in the territory from which the institution draws its support. Since institutions similar to the average middle western university have been in mind during the outlining of the course and as most of these schools are in close touch with the type of industry mentioned above, it is believed that this course could best be developed in one of this class of institutions.

Possibly the best means of presenting this material will be to outline in tabular form the course as it has been developed and then to discuss and clarify the reasons for arranging the work as it is. The question of credit has not been introduced for that is more or less a matter of detail and depends to quite an extent upon local conditions. The purpose here is only to indicate the relative emphasis and amount of time which should be placed upon the various phases of the course. This outline is shown in the accompanying table.

No doubt there are some subjects here included which some metallurgists would not include and some not included which might be preferred. This outline is only presented as a starting point for discussion. There is no question about the fact that discussion and criticism would bring out some very useful points in regard to the character and arrangement of material in such a course.

Certainly the first thing to be done is to justify the course in the review of elementary mathematics which appears in the first college year. One of the most discouraging things which the writer has been confronted with in his teaching experience is the apparent inability of the average university sophomore to make much application of the principles of percentage, ratio and proportion, etc., which he supposedly studied in the fourth grade. This also applies to work which involves

A paper presented by title at the Indianapolis Convention. The author, W. P. Wood, is assistant professor of chemical engineering, University of Michigan, Ann Arbor, Mich.

the solution of quadratic and simultaneous equations. It is believed that a large proportion of university instructors have noticed the same thing. It is not thought that the secondary schools are altogether to blame. The difficulty comes in applying the principles of arithmetic, etc., to concrete engineering problems which arise, and it is just this which the writer has in mind concerning the course mentioned. Two objects would be accomplished: (1) The review of simple but not always familiar principles; and (2) an introduction to some simple engineering problems.

With regard to the mathematics which follow this first course mentioned, little need be said. It involves nothing more than a thoroughly trained metallurgist should have in order to handle intelligently the modern problems which are requiring more and more theoretical training.

OUTLINE OF COURSE

First Year

First Semester	Second Semester
1. Review of Elementary Mathematics	1. Algebra and Analytic Geometry
2. English or General Chemistry	2. English or General Chemistry
3. Descriptive Geometry	3. Descriptive Geometry
4. Language	4. Language
5. Shop Work	5. Shop Work

Second Year

1. Algebra and Analytic Geometry	1. Calculus
2. University Physics	2. University Physics
3. Language	3. Language
4. Qualitative Analysis	4. Quantitative Analysis
	5. Fuels and Combustion

Third Year

1. Calculus and Differential Equations	1. Kinematics
2. Organic Chemistry	2. Heat Engines
3. General Metallurgy of Iron and Steel	3. Machine Design
4. Physical Chemistry	4. Metallography of Iron and Steel
5. Strength and Testing of Materials	5. Metallurgy of Nonferrous Metals and Alloys

Fourth Year

1. Thermodynamics	1. Pyrometry
2. Furnace Design	2. Electrical Engineering
3. Engineering English	3. Special Metallurgical Problem
4. Options	4. Options

The writer is firmly convinced that the best road to complete mastery of a subject lies in the ability to make calculations involving the principles of the subject.

The shop work in the first year would include forge work and foundry practice. The aim should be mainly the acquiring of the shop atmosphere and methods. Supplementary recitations would serve as a means for introducing some of the simple theoretical considerations such as the presence of critical points in steel, reasons for forgeability of wrought iron and mild steel, and general effects of chemical composition upon the character of metals.

It is presumed there would be some argument about the language which occurs in the first two years. If this were a trade school course, language probably would not be included, but there is always a certain amount of culture which is inseparable from a university degree and this means the inclusion of some subjects which do not have a di-

rect bearing upon the subject and tend more to round out the student into a well informed man of the world. No one really could call himself a broadly trained metallurgist who has not some familiarity with at least one foreign language.

The physics in the second year would be similar in all respects to the present courses in university physics. There is less quantitative analysis included than is customary in many courses of chemical and metallurgical engineering. The writer believes that a metallurgist should understand the principles and practice of quantitative analysis, but does not necessarily need to become an expert in it. It will almost never be necessary for him to make routine analyses.

Study of physical chemistry should be elevated to a point of great importance. It might even be possible to call this course "physical metallurgy," but such a designation would not include the very useful and necessary review of chemical principles which physical chemistry involves. At any rate the course should make very clear the great application which physical chemistry has in the field of metallurgy.

In the fourth year, the courses with two or three exceptions are probably open to more criticism than most of those which precede. The writer believes, however, that thermodynamics should be included among the required courses, for the application of this subject to metallurgy is too little appreciated. The metallurgical engineer should also have some knowledge of the principles of electrical engineering and the necessity for this will become greater in the future as the use of electrical furnaces increases. The courses in pyrometry and furnace design might be included among options, but the writer is unable to see any situation where the metallurgical engineer will not have to concern himself with these subjects, particularly pyrometry.

The course entitled "special metallurgical problem" is no departure from the practice of the majority of engineering schools. It is here that the embryo engineer is supposed to obtain his practice in attacking a concrete problem in his chosen field. The value of such a course is well recognized and no doubt few people would wish to dispense with it.

In conclusion, one of the criticisms which would most probably be made of this curriculum is that there are not enough options. There is a danger in laying out a course of study which allows a too large number of options. The natural tendency for the average student is to elect subjects along the line of least resistance which leads to anything but a well rounded education. On the other hand, too stereotyped a course is not desirable since it leads to over specialization. The aim should be a happy medium between required work, and a choice of options which is wide enough to enable the student to become a broad minded engineer, without permitting such latitude that the selection of options becomes a mere searching for the easiest courses.

BUYING STEEL ON CLOSER CARBON LIMITS

By E. W. Pierce

OWING to difficulties experienced with steel sold under certain specification numbers allowing for a variation of carbon of ten points, a closer specification limit of as low as five points is advocated. This covers directly, steels heat treated for parts afterwards machined and steels used for carbonized parts. This particular demand is made as a means of reducing shop costs to the fabricator in the handling of material in the various shop processes.

Under the present mode of buying and selling steel based on the Society of Automotive Engineers' specifications, the carbon content of each specific grade is allowed a ten point range, that is a 1040 steel permits of steel running from 0.35 to 0.45 per cent carbon, and so on with the balance of the specification numbers.

On general appearances this permissible range seems quite satisfactory. It is especially of benefit to the steel manufacturer as it is obvious that it permits of less particular attention to the heats and gives him a greater range on which to fill orders. On the contrary it is not so favorable to the buyer who later must forge, heat treat and machine for use in the finished or fabricated state.

In the process of manufacture, each heat is numbered and the chemical analysis obtained is recorded with the heat number. The S. A. E. number for the heat can be given and the steel is so classed for storage or shipment. The steel is now ready to be used by the fabricator and to undergo the various processes necessary for its completion as a finished product.

The buyer, when ordering from the mill, gives his order in accordance with the S. A. E. specification requirements. The usual specification for a straight carbon stock for carburizing is S. A. E. 1020, permitting stock to be issued running from 0.15 to 0.25 per cent carbon. Lower amounts are often used and where possible to obtain such low carbon content, it is possibly better. To obtain a carbon content of 0.20 per cent is the usual practice, or at least from 0.15 to 0.20 per cent, and this amount always has produced excellent results for this particular work. However, when the carbon content approaches the upper limit of 0.25 per cent, the quality of the resultant product is considerably reduced. Higher carbon within the specification limits impairs the toughness of the part and makes it much more brittle under impact. Core refining heats, to some extent, may remove this trouble but not entirely.

Parts of delicate design and having thin surfaces to carburize require as low a carbon content as possible, as the hardening strains set up are greater than in the heavier constructed parts. High carbon stock of 0.25 per cent has been found to crack very readily under the above conditions. Lower carbon content increases toughness, increases resistance to impact and reduces the danger of cracking in hardening.

Now let us take, for example, an order calling for a 1040 steel. The steel plant can fill this order with a product having a carbon content

---

A paper presented at the Indianapolis Convention. The author, E. W. Pierce, is chief metallurgist, Maxwell Motor Co., Newcastle, Ind.

anywhere from 0.35 to 0.45 per cent, and suppose it is filled with that having a 0.35 per cent carbon content. They are perfectly justified in so doing. But suppose the mill cannot supply this material all from one heat and it is necessary to use material from other heats; then there comes the danger of supplying steel which varies considerably from the analysis of the original heat but within the specifications, say 0.43 per cent carbon. We would then have a steel shipment of a 1040 grade which would have a carbon variation of 0.08 per cent.

When the material is received in the forge shop of the buyer, it is cut to length, stacked and marked as 1040 steel and later delivered to the hammer as such. In the forging, however, no great difference is noted as the forging heats are usually high enough to insure easy working of the steel. During the process of shipping, cutting and stacking and delivering to the hammer, and further in the forging operation itself, the steel becomes thoroughly mixed and the material, although possibly shipped in two grades of 1040, is now inseparable.

In this condition it is brought into the heat treatment to be hardened and drawn to meet the various tests prescribed by the engineering department. These tests, as you know, cover the various physical tests and hardness tests. Further than this, the product, as it comes from the heat treatment, must be uniform in all respects and particularly as regards machinability. Too great stress cannot be put on this latter quality as it is directly responsible for the rate of production and the efficiency of the machine shop.

The evils of nonuniformly machinable steel are many and costly. First, the product itself will vary in quality and service to the ultimate consumer, the one place where it must make good. This, however, may be classed as an indirect evil. The more apparent and the more to be considered faults to the manufacturer are increased tool costs due to breakage and burning, waste of time of operator in changing and regrinding tools, waste of material and, further and most important, decrease in production.

Nonuniformity in hardness is, of course, the direct cause of many machine shop troubles and is due to the manner in which the material is hardened. The better hardening conditions require quenching at or just above the critical temperature to insure good structure as well as good physical properties. It has been found that steel, varying as much as 0.08 to 0.10 per cent carbon on hardening, will produce quite a variety of results as regards hardness. Actual tests have shown a scleroscope difference of 15 to 20 points where the variation is as much as 0.10 per cent.

Therefore, it is obvious that material varying on a ten point limit cannot be hardened satisfactorily and give the proper structure as well as physical properties with the proper hardness. In cases of this nature, it is impossible to draw back a heat evenly and give it uniform hardness.

Many small parts often require as high a hardness as is possible with good machine shop practice. On heat treated work which is passed on a 10 per cent scleroscope inspection and using a grade of steel varying as pointed out above, it is practically impossible to maintain the required high hardness without a few parts getting by which will give trouble in machining. In order to get by this trouble it is a case of giving the entire product a 100 per cent inspection.

With this remedy for surmounting the difficulties of uneven hardening, additional costs have been added to factory expense or overhead, as inspection is usually charged to this account. In either case, the cost of handling steel of such wide variation is of considerable consequence and is well worth looking into. As a means of eliminating the entire expense to the manufacturer, whether charged to production or overhead, let the buyer require that his steel be sold on closer specifications, and further, that the carbon content be maintained within a five-point limit.

This requirement on the steel mill is not excessive and is, in fact, being done at some mills at present. This closer limit can be obtained through the better methods of manufacturing by which the steel is more absolutely controlled. With better determined loss of constituents, it is possible to make a steel within the carbon limits, as well as within closer limits on chrome and nickel. Further, improved methods in casting will cut down carbon segregation within the ingot itself.

Discussion of Mr. Pierce's Paper

MR. PIERCE: At the time the industrial depression took place our company, as well as some others that I have been familiar with, was found to have an unbalanced inventory, which was particularly noted in the material stocks. During this time of depression and readjustment, it has been necessary to work off this material in the best manner possible. Therefore, we took a very thorough inventory of our stock and found that we had considerable quantities of various grades of steel, very much within the same carbon limits, but still varying considerably, which would give us trouble later on.

It had always been our custom to buy our steel and have the lot number and the heat numbers accompany the shipment, and the material was always stacked and sorted in this manner. But when it came to readjustment these various quantities were selected according to S. A. E. specifications, as nearly as possible and stacked as such. During the time after that, during our production, we had considerable trouble with the heat varying in carbon content, which gave us trouble in the hardening room as well as in the machine shop.

Therefore the idea seemed to be that it would be much better if the specifications could be narrowed down and brought down to at least a five-point limit. In this manner we believed that we would eliminate considerable shop trouble throughout the plant in the hardening room, as well as in the forge shop. Thus this short article has been written arguing for a five-point limit on steel for carbonizing purposes as well as heat treatment.

MR. STAFFORD: I would like to ask the speaker if he has been able to buy any steel, ordinary hard steel, where he could specify a five-point limit?

MR. PIERCE: We have been able to do that recently, owing to the fact, I suppose, that there is greater competition in manufacturing and in selling. I will admit that previous to the last few months we were not able to do that, but it is an actual fact that we have bought steel on those terms. I might say further that where the range of ten points is allowed, it often happens that shipments will come in that are, say, two points under or even two points above, and it is very rare

that they are turned down on a two point basis. Allowance usually is made for this amount. Therefore, practically the variation is as high as 14 or 15 points, whereas if the steel can be kept and bought within a five-point limit, if it cannot be absolutely controlled within the five points, we are absolutely sure that it will be within the ten-point limit.

Further than this, it is impossible on a large production scale to harden heats individually and follow them through the shop because it requires that each particular heat must be kept separate so that it can be treated properly, and when it comes into the machine shop it also requires additional attention in the setting up of machines for proper and efficient machining. So where we can rely on the fact that our scale will come within these limits, the operation in the heat treatment and in the machine shop itself has been reduced, as regards costs and efficiency of handling.

A SUCCESSFUL BONUS SYSTEM APPLIED TO HEAT TREATING

By A. A. Blue

IN general, so-called bonus systems are developed primarily, with the purpose of increasing quantity of production and secondarily, increasing quality of production, or a combination of the two, resulting in increased returns to the plant owners, the activating agent being increased pay to the men employed upon the work. The fundamental principle involved is simply one of stimulating the worker's interest in his task, for no one can do anything well in which he is not really interested, hence we have bonus systems, golf tournaments and world's baseball series. However, no one feels an interest in any competition or effort which he does not believe to be fair, and in which he lacks confidence as to its stability. Lack of care and study in the past with respect to installing bonus systems and setting rates has caused a natural and wide spread distrust of such matters to grow in the minds of most men.

These systems can only attain the maximum degree of success where the management has taken every precaution to establish equitable rates, and has then developed a reputation for maintaining these rates. Rates that are too low naturally fail to interest the men, and rates that are too high work an injustice to the management, and further injure the workmen as well. There is an inherent sense of the fitness of things in everyone, to a greater or less extent, which will show itself in time in some manner or other, so that the average man receiving an excessive rate cannot long be content and maintain the necessary interest in his work, and the employer will shortly lose a formerly good man, and the man lose a job that was too good for him. This has been an all too familiar occurrence during the war period. Such conditions are injurious to all concerned and cannot be too carefully guarded against.

Turning from general principles, there are a number of practical details that must be satisfactorily taken care of in any successful bonus system, thus, (1) the figures must be easily and cheaply calculated and they must be accurately obtained; (2) the flexibility of the organization should not be greatly affected by such an installation; (3) it should apply to all articles manufactured, that is, it should cover a large variety of products; (4) it must obtain co-operation between all employes, those on the same shift and those on all shifts; (5) complete records should be kept of all details, preferably by the men themselves, with suitable checking, as it is only human nature to do one's best when the results go down on paper and are received by one's superior.

The bonus system described in the following paragraphs has been worked out on the general principles outlined above, and applied to a heat treatment department with marked success. Heat treatment, being pre-eminently a quality operation, this aspect has been emphasized to a high degree, as compared with quantity. The actual details are embodied in the following announcement, issued to the men in the department over a year ago:

"The following bonus regulations will be in force for the men in the heat treating department:

Heaters: Heats are to run according to the following regulations:

(1) Temperature: The temperature, after the material is soaked out, must be

---

A paper presented at the Indianapolis Convention. The author, A. A. Blue, is metallurgist, Duff Mfg. Co., Pittsburgh.

kept within these limits:

Annealing and carbonizing: Plus or minus 20 degrees Fahr.

Quenching and drawing: Plus or minus 10 degrees Fahr.

(2) Time: The times for heats in the various furnaces are as follows: No. 1 and No. 2 furnaces—Soak out in 1 hour, hold ½ hour, total maximum time not over 2 hours. (Similar figures were included for other types of furnaces.)

The number of heats run by each heater within the above limits will be figured on a percentage basis for a week's time and bonus paid as follows:

Efficiency Per Cent	Bonus per hour	Efficiency Per cent	Bonus Per hour
90	$0.005	96	$0.06
91	0.01	97	0.07
92	0.02	98	0.08
93	0.03	99	0.09
94	0.04	100	0.10
95	0.05		

The temperature will be taken from the record on the pyrometer. In case of instrument trouble, the heat will not be considered either way, unless the heat was "off" before the trouble occurred.

The above times are on the basis of the following minimum weights per furnace charge:

No. 1 and No. 2 furnaces—300 pounds, etc.

(As above, similar figures were prepared for each type of furnace). The time will be counted from the last piece charged into the furnace to the first piece pulled out and shall be so entered by the foreman on the ticket. The foreman shall inspect all heats when "soaked out" and note this time on the tickets, also. Each heater will be required to run from 1 to 4 furnaces.

In case of a heat running from one shift to the next, the heater having run it the greater length of time will be responsible.

Exceptions to the above are (1) die blocks; (2) ball races; (3) shear blades, where the temperature only will be considered.

The above times are based on the continuous operation of a hot furnace, and do not apply to the first heat in a cold furnace, when the temperature only will be considered.

Helpers: Helpers will be paid a bonus on the following basis:

Pounds per furnace-hour	Bonus per hour	Pounds per furnace-hour	Bonus per hour
170-180	$0.01	220-230	$0.06
180-190	0.02	230-240	0.07
190-200	0.03	240-250	0.08
200-210	0.04	250 and over	0.10
210-220	0.05		

These figures are obtained by dividing the total weight of material handled during the week by the number of hours all active furnaces are in operation. When all work for a furnace has been completed, this fact will be reported by the foreman and the furnace will not be counted as active again until more work arrives.

The figures are "over-all", taking into account all work done, that is, carbonizing, annealing, quenching, etc. Men on both shifts will receive the same bonus. Work handled twice will be considered as double weight, that is, material quenched and drawn back will be counted twice. Likewise, material double-quenched will be counted twice.

Work which fails to pass test on standard treatments will be retreated to pass without credit being received towards the bonus.

The weight handled will be based on the count made by the inspector and each ticket must bear the inspector's OK for the count.

Foremen: The foremen will each receive 10 per cent of the total bonus in the department.

No man will receive any bonus for any week in which he has been absent, unexcused."

The conditions obtaining in the department to which this system was applied cover a wide variety of work, such as (1) all types of commercial drop forgings for the automotive and other trades; (2) all vital steel parts used in the manufacture of various types of high grade lifting jacks, such as carbonized gears, high carbon, high chrome ball races, nickel

chrome pinions, lifting racks, etc.; (3) drop forge die blocks, trimming knives, etc. Three types of furnaces are used, necessitating different standards as to weight of charge and time of heating for each type. A well known recording potentiometer system is employed for measuring temperatures, one thermocouple being suspended in the front and one in the back of each furnace, the ends of the couples being in actual contact with the charge in the furnace at all times from the moment the charge is in place until it is ready for removal. Immediate discharge is the penalty for anyone tampering with these couples during the operation of a heat.

Form 322 5M-1-21

DUFF MFG. CO.

HEAT TREATING DEPT.

Part No. AB-418 Name Connecting Rod Qnt. 150

Count ok. Inspr.

OPERATION	START	SOAKED	FINISH	CHECK NO.
Charging				
Annealing				
Carbonizing				
Quench	830 AM	940	1010	283
Draw	1120 AM	1155	1225 PM	283

Date 8-25-20 Shift Day Furnace 3-619-4

Treatment 1600 – Water
1080 – draw

REMARKS ON BACK

J. Jones
FOREMAN

Fig. 1—The standard form or ticket for each lot of material treated, giving spaces for entering all information concerning the nature and quantity of the heat itself, together with data as to length of time in furnace, heater's check number, date, treatment and the furnaces employed. The number following "Furnace" indicates the furnaces used and the heat number, thus, here the heat number was 619; the first heat was received in furnace No. 3 and the second in furnace No. 4. All such records are gone over by the foreman of the shift and personally signed by him before being turned into the office. The inspector then checks the count made of the number of pieces, making the necessary notation of the face of the report

The men employed are, as noted above, divided into heaters and helpers. The former have to do only with heating the furnaces, superintending the location of the charges in them, and keeping the burners, etc., about the furnaces in condition. The latter do the heavy work, such as charging the furnace, pulling the heats, quenching, etc. A foreman is, of course, in charge of each shift.

Referring now to various features mentioned in the introductory paragraphs, and examining them as applied to the present instance, we find,

(1) *Quality.* The heater is chiefly concerned with the quality of the

product, as measured by the accuracy of the temperature control. Actual figures of the results obtained are as follows: The first week in which the system was in force showed two typical heaters with averages of 74.5 and 81 per cent. The second week their figures were, respectively, 97 and 96 per cent; the third week, 95 and 96 per cent. In a year's time, covering all sorts of conditions of business, labor, etc., in only two instances has the maximum been reached and in three cases have heaters failed to make some bonus. The general effect can be compared closely to the governor on an engine. If a man has been averaging 95 to 96 per cent and becomes a little careless, with a resultant drop to 90 or 91

Table I

Bonuses Earned in Week Ending Sept. 25, 1920

Heaters

Name	No.	Efficiency per cent	Rate of Bonus
Murphy	219	87	No bonus
Lewis	225	95	$0.05 per hour
Jenkins	230	96	0.06
Ross	283	94	0.04

Helpers

Total weight handled, pounds	162,444
Total furnace hours	692
Pounds per furnace hour	235
Bonus rate per hour	$0.07

This rate applies to

Name	No.
Lutz	218
Lehman	220
Kopf	222
Hindman	231
Salvo	270
Livitz	250
Kimick	242
Marunchek	234

Foremen

Total bonus for week	$45.00
10 per cent of same	4.50

This applies to

Name	No.
Welty	278
McGregor	272

per cent, the effect upon the following week is always most marked, as the increased attention resulting from the lower figure invariably results in a very good week with possibly 98 per cent average. The temperature limits prescribed are well within the range of possibility for ordinary shop furnaces, and at the same time, amply close for accurate heat treatment. In some cases, of course, such accuracy is not entirely necessary, but the effect of impressing upon the men the need of such care in each and every case cannot be overestimated, as it is only upon such a foundation that constantly reliable results can be obtained. In most instances, even where the recorded temperatures do not fall within the specified limits, the divergence is so small that the work will pass test anyhow, and the instances of retreatment have been very few indeed.

Quality is also taken care of by the helpers to the extent that they are held responsible for the proper quenching of material, inasmuch as any parts failing to pass test after receiving a well established treat-

ment, must be retreated without credit being received for the weight handled. This circumstance, too, has been met with in less than a dozen instances.

(2) *Quantity.* In addition to his quality concerns, the heater is further interested in quantity to the extent that he must run out a

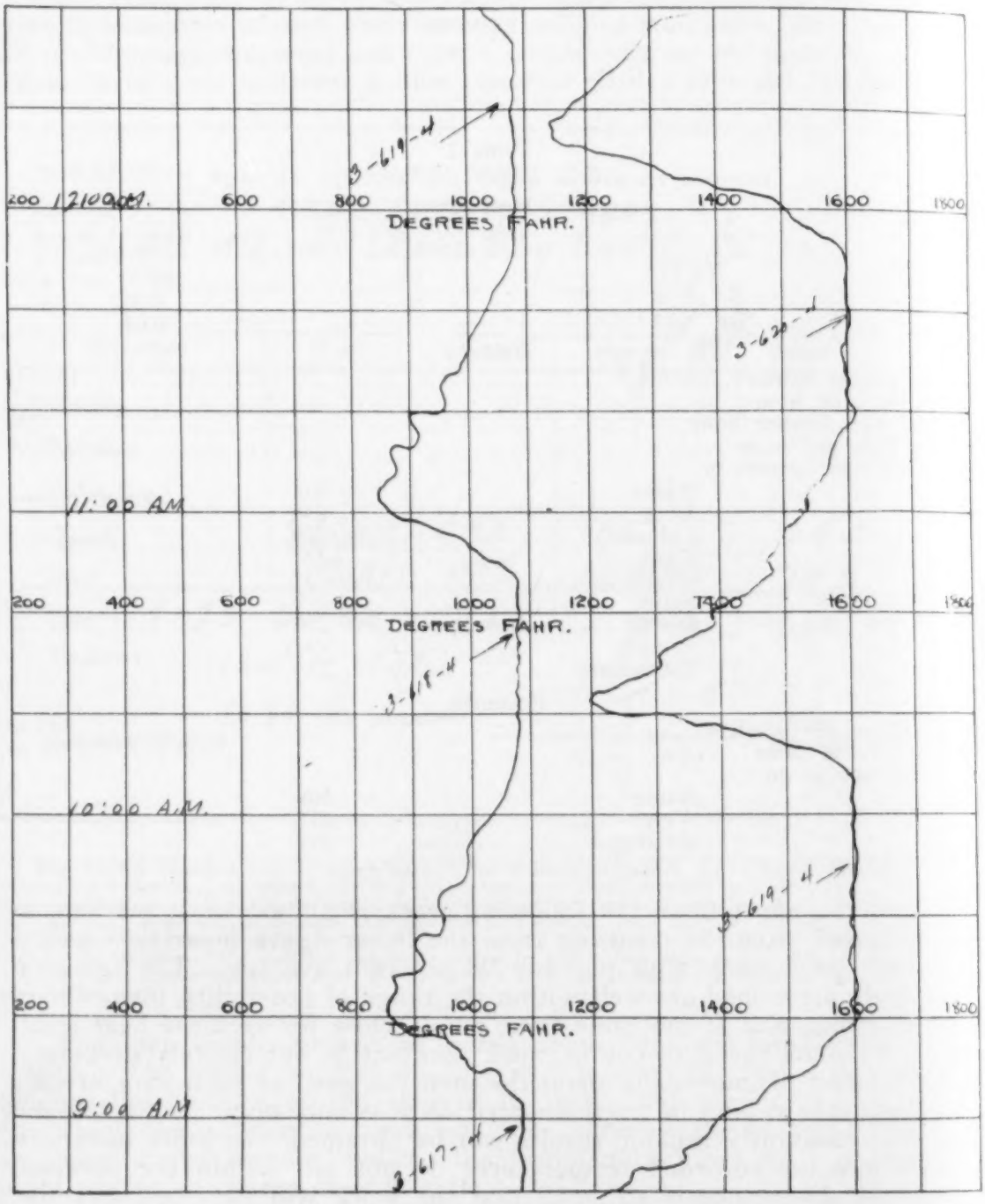


Fig. 2—The report shown in Fig. 1 is checked in the office against the record chart of the furnaces. Above is shown a portion of such a chart, showing the simultaneous records of two furnaces, No. 3 and No. 4, the former at the quenching heat of 1600 degrees Fahr., and the latter at the draw temperature of 1080 degrees Fahr. The accuracy of these temperatures is noted and, if within the tolerance allowable, bonus is credited towards the heater concerned. The various heats are at the same time identified with their respective numbers to facilitate future reference

heat of a certain weight in a definite time to score on his average for the week. The helpers, however, are primarily interested in quantity, and it is at all times to their advantage to clean up the work promptly, the bonus being paid upon a compound unit, involving not only weight but time. The heaters and helpers act as a "check and balance" system, the one on the other with respect to quantity, it being to the heater's advantage to charge the furnace as near as possible to the low limit, so that he may more readily meet the time element, and the helper's advantage being best served by a maximum load in each furnace. Practical results from the quantity viewpoint are as follows: Previous to the installation of the system, the "pounds per furnace-hour" were found to average 150 to 160. This was felt to be low, reference to the above tables showing the higher values actually determined upon. The following figures were realized in successive weeks after putting in force these regulations: 245, 249, 235, 208, etc. These rates have, indeed, been very happily selected, as the men have in every instance made some bonus, and, up to the present time, have not yet succeeded in reaching the maximum.

(3) *Ease and accuracy of computation.* All the necessary figures to compute the bonus rates are obtained from two records, one, Fig. 1, being a record or "ticket", made out for each furnace charge, and the other, Fig. 2, coming from the automatic record of the potentiometer. The importance of records in heat treatment work can scarcely be overemphasized, so that these two forms are, in the writer's opinion, necessary to any well-run department whether using a bonus system or not, and they are not, therefore, any burden chargeable to such a system itself. These "tickets" and furnace records are gone over each morning in the office for the previous 24 hours, and the weights and good and bad heats readily recorded. At the end of the pay period, it is a simple matter to obtain the final figures. The unit, "pounds per furnace-hour", is not a sensitive one, and when taken in groups of ten, a small variation in time or weight produces no appreciable change in the result. The inspector's count of material handled insures accuracy as to weight, and the temperature chart is made automatically by a machine under lock and key. Table I shows a typical report of a week's bonus for the men.

(4) *Flexibility of system.* In general, most work of a large heat treating department is of standard material. In cases, however, where such is not the case, the time element on heats is waived, and temperatures only are considered. This is noted in the announcement quoted above in respect to die blocks, etc.

(5) *Variety of work covered.* The range of work to which this system is applied is quite large, as noted above, and very careful study was made to secure figures that should be applicable to a wide line, such as ordinary annealing, hardening, and special work as die blocks, carbonizing, etc.

(6) *Co-operation of employes.* This desirable feature is largely obtained by clubbing together the bonuses of both shifts. Thus, there is no tendency for one shift to leave the shop in a poor condition for the incoming men. It is also to the advantage of the foremen to maintain harmony throughout, as their own bonuses depend in turn upon

the amount of the bonus which is earned every workman in the organization.

Two criticisms that may be urged against the present plan come to mind as follows: First, in the case of absence of a helper, additional work is thrown upon his associates with the probable result of a lessened bonus and more work per man. In practice, however, it has been found that the penalty attached to absence has practically negatived this consideration. Second, it may be felt that the helper should not receive the same bonus rate for handling one heat per day in slack times, as for six in busy times. In such a connection, it should be considered that by their handling the work promptly and not "lying down" so as to lengthen it out, the fuel necessary is reduced, less scale is formed upon the product, and the wear and tear upon equipment is minimized. It has thus been the writer's experience that such a provision is justified in the long run.

The success of the above installation has been due, as explained in the opening paragraphs, to being in happy accord with the underlying principles involved. All rates and figures were set as the result of over six months careful study of all conditions. The result has been most fortunate in that they have never been altered, the men thereby have confidence in the management, and while making some bonus every week, have scarcely yet attained the maximum, giving a constant incentive and maintaining the interest. Aside from the money stimulant, it is of considerable satisfaction to Mike to know that he ran 96 per cent of his heat correctly, while Joe got but 93 per cent, the records being made automatically under their own eyes. The men pay much more attention to the condition of their furnaces, too. Dirty burners and loose bricks do not aid in running accurate heats and are promptly attended to. The helpers always have a charge of material waiting beside the door of each furnace ready to go in the moment the present charge is removed.

All this is done with a relieving reduction in personal friction, haggling and other such disagreeable features so prevalent under other conditions, so that the system may almost be regarded as automatic. This is simply due to the fact that right or wrong is so sharply defined. Either a temperature record is OK or it is not, and having been automatically made by a reliable machine, cannot be disputed. The weight report is dependent upon the count of an impartial inspector under a chief inspector, and no argument arises from this source. The men know if they work hard, they will receive a fair bonus, and if they do not, they get no bonus, so that they go to it. Practically the only friction caused by the regulations came in the first week, when two men quit, after being refused bonuses on account of absence. The rule was strictly adhered to and has caused no trouble since.

The system just described has been of considerable value to the author, and it is hoped it may contain suggestions that may prove of value to others in similar work.

THE HEAT TREATMENT OF STEEL CASTINGS

By Walter H. White

ALL steel castings, no matter by what process they are made or for what use they are intended, should be treated to relieve the strains set up during solidification. Success can be had with various types of furnaces, the principal requisites being:

1. A uniform temperature should exist throughout the entire heating chamber.
2. The furnace should be always under control of an experienced operator.
3. The pieces should be heated uniformly from all sides.
4. A temperature indicating instrument should be used in every case.

Solid fuel, oil, gas or electricity may be used for heating. Heat converted from electric energy is the cleanest, safest and easiest controlled, but in most cases is too expensive.

Where castings of a like size and like composition are treated day in and day out, if the quality of steel is good the heat treatment department can soon establish a practice that will accomplish good results and pass any necessary tests that are required. It is in the jobbing shops making castings weighing from 10 pounds to 50 tons and bearing different compositions that the heat treatment department has its trouble, and for this reason specifications should be outlined and the melting department should be compelled, in so far as it is practical, to furnish castings within these specified limits. These limits, of course, are made according to the work required of the particular casting in question.

Many workmen operating heat treating furnaces know how to load their furnace; that is, how to place their castings so they will not distort; how to control their fire and how long to heat and soak. This knowledge has been gained through experience which has cost some company many dollars before this particular state of perfection has been reached. Many of these same men, if in their early days of experience had been trained under more scientific methods and taught enough of metallurgy to give them the knowledge of why they heat to a certain degree and why they soak for a certain time, would have saved money for the company and would have improved their personal knowledge of steel treatment, thus fitted themselves for better positions. It reminds one of the story of the old railroad man who was being retired after 30 years of faithful service. The officials gave a banquet in his honor and each had something to say in his behalf, giving figures as to how many thousands of wheels he had inspected, how many hammers he had worn out and how many miles he had walked. One official finally asked him why he struck this steel wheel with the hammer, and he answered, "In all my years, I never knew." So it is with some of the old time furnace operators, only it may not be so bad as this particular case. Some steel men who have gained a certain amount of knowledge have been reluctant in giving the other fellow the benefit of their experience and thereby to promote the progress of the steel industry. This type of man is fast disappearing and with his disappearance, progress is being made.

A paper presented by title at the Indianapolis Convention. The author, Walter H. White, is superintendent of melting shops, United States Naval Ordnance Plant, Charleston, W. Va.

First, when a heat of castings is passed to the heat treatment department, chemical analysis should be known and each casting, no matter how small, should be stamped with the particular melt heat it was cast from. Second, the department should know the physical results desired and possible from these castings. Third, the department should know the classification of size and chemical composition; that is, carbon and manganese of a maximum and minimum content for each heat treatment. The results under this practice will be more consistent if the practice is outlined by the proper persons and the operation carried out according to instructions.

Better results are being accomplished today in the shops where electric control instruments, such as indicating pyrometers, recording pyrometers and automatic control boards, are in use than in the shops where such instruments are not being used. The progress made has been excellent, but is not due wholly to the use of scientific instruments, special design of furnace or individual efficiency of the heat treater, but due in part to a better steel being made by the steelmaker. It is impossible for the heat treatment department to obtain certain standard results from all castings sent to them for treatment, even though they are all of the same design and composition. The history of the melt, which begins with the charge selection and ends with the shipment of the heat, covers a passage that has many problems, which if not solved properly by the steelmaker, causes the steel treater no end of trouble, for it is impossible for him to treat bad material but possible for him to get excellent results from good material, if these problems have been solved.

Of all the steel melting furnaces used for the manufacture of steel castings and forgings, the electric furnace offers to the steel industry the best unit for the steel treater. This is due to the following reasons: The best range of composition can be set and the limits made to a minimum. Eight points of carbon, 10 points of silicon, 10 points of any other alloy with a maximum of 0.02 phosphorus and 0.02 sulphur is a sufficiently close range for any electric melt shop to work on. The writer is connected with one of the largest electric furnace plants in the country and with the above allowance, making most alloy steels, can vouch for the fact that not more than two off heats have been made in the past year.

A. N. Canarroe in his paper published in the April, 1920, issue of the *Steel Treater's Journal,* touches on many defects that can happen in steel castings due to melting practice, and any one of the many he mentioned is sufficient to make the steel treaters' results unsuccessful. The first he speaks of is temperature, and this is one of the most important. When one speaks of electric steel they think of it as always being very hot because the electric arc is possible of intense heat, but that is no reason why the steelmaker cannot control his temperature for tapping. Duplex heats from the open hearth to the electric are being made where the tapping temperature from the open hearth furnace is hotter than the tapping furnace temperature of the finished product from the electric furnace.

It is believed most open hearth and electric furnace plants have been pouring their castings at too high a temperature, and where the defect does not show on the surface as a crack or check, due to ratio of solidification of heavy and light sections, it is in the casting as an excessively large crystal, due to the steel holding temperature in the granulating range for too long a time. This is due primarily to too high a casting

temperature. Another serious trouble is the blow hole which may be due to improperly dried molds or the steel not being properly killed or deoxidized.

The question of working the steel in the liquid charge to eliminate certain injurious gases, covers a large field and would come under another subject. The question of wet and improperly vented molds is a simple problem and due in the majority of cases to lack of judgment on the dry floor foreman's part. Sonims or solid nonmetallic impurities can be controlled to a minimum by not using aluminum, or using it sparingly; good clean ladle practice; the use of high grade refractories; clean mold practice; judgment in selection of charge and balanced composition of finished product; and above all, absolute control of the melting heat from power on to tap with proper slag conditions existing when the heat is ready to pour.

No trouble was experienced on the following steel castings weighing 6000 and 600 pounds respectively:

6000-Pound Solid Round Casting Composition

Carbon per cent	Manganese per cent	Silicon per cent	Phosphorus per cent	Sulphur per cent	Nickel per cent
0.32	0.73	0.25	0.021	0.017	3.15

Treatment

Heated to 1500 degrees Fahr., soaked 6 hours, quenched in water.
Heated to 1250 degrees Fahr., held 8 hours, cooled in furnace.

Results

	Tensile strength pounds per square inch	Elastic limit pounds per square inch	Elongation per cent	Reduction in area per cent
Required	85,000	53,000	22	35
Obtained	97,800	75,600	22	39

120-degree cold bend satisfactory

600-Pound Cone Shape Casting Composition

Carbon per cent	Manganese per cent	Silicon per cent	Phosphorus per cent	Sulphur per cent	Nickel per cent
0.36	0.75	0.21	0.019	0.011	3.08

Treatment

Heated to 1500 degrees Fahr., soaked 6 hours, quenched in water.
Heated to 1250 degrees Fahr., held 6 hours, cooled in furnace.

Results

	Tensile strength pounds per square inch	Elastic limit pounds per square inch	Elongation per cent	Reduction in area per cent
Required	85,000	53,000	22	35
Obtained	97,100	70,800	24	45.3

120-degree cold bend satisfactory

With good steel and the above treatment, it was possible to pass 98 per cent of castings of the above composition submitted for test.

The following results were obtained from a simple steel casting weighing 300,000 pounds:

300,000-Pound Steel Casting

Composition

Carbon per cent	Manganese per cent	Silicon per cent	Phosphorus per cent	Sulphur per cent
0.26	0.66	0.17	0.028	0.025

Treatment

Heated to 1750 degrees Fahr.	Hours
Time to reach temperature	40.5
Time of soaking	48
Held after soaking	30
Cooled in air	
Furnace closed	27

Furnace opened	5
Furnace closed	28
Low oil on	12
Cooled in air	
Furnace closed	74

The above treatment required 11 days. As the casting was only partially cleaned, it was finally finished and recharged for the following treatment:

	Hours		Hours
Time to reach 900 degrees Fahr.	17	Held	2
Time to reach 1270 degrees Fahr.	8	Held	5
Time to reach 1600 degrees Fahr.	12	Held	55

Cooled in furnace for 6 days.

Results

Tensile strength pounds per square inch	Elastic limit pounds per square inch	Elongation per cent	Reduction in area per cent
65,000	23,000	24	45

The length of time and the care taken in the above treatment was necessary to insure the physical results and to prevent the casting from cracking during treatment.

H. S. Wilson's advice as to taking small samples of bar steel as received from the mill, place them in the furnace, and as the heat rises to remove them one at a time at various stages—the last one, if possible, at the burnt stage, is well worth trying on many classes of stock steel. As he plainly brings out the fact that transition from hard to soft is in an extremely short range, it is possible to cast from each melt certain standard bars that could be handled in the same manner as this test. That would be a guide to the treatment of simple or alloy steel castings, it being more important with the alloys than the plain steels.

This has proven to be good treatment for certain annealing heats, composed of five different open hearth heats, for four of the total of five open hearth heats, and every casting in a certain particular open-hearth heat would fail on physical test. Such a condition as this proves conclusively that the steel in this one open-hearth heat was bad before it was placed in the annealing furnace with the other four good heats, which passed a successful test of pulling a bar from each casting.

No heat treatment, no matter how well handled, will obtain certain results from poor steel, and for this reason those responsible for heat treatment of steels, should consider their profession as only complete when they have obtained a true knowledge of the melting and mechanical process through which this steel has passed. In many cases accurate melt records, properly kept and passed upon by experienced men, would reject many ingots as cast, thus saving the cost of mechanical treatment and heat treatment. This may sound impossible, but it is a fact. It is reason for the steel treater familiarizing himself with the melting and shaping of steel that he may know all of the history of the product he is handling.

RECONNOITERING IN AUTOMOTIVE CIRCLES

By V. A. Crosby

WE ARE passing through that sector of the circle of business known as "readjustments". It is quite hard to designate the beginning and end of any one of the four sectors of the circle in which our industrial life travels. The period just referred to is so closely related to the period of depression that the two may actually, in many cases, happen together; however, as a general process, hard times or depression are followed by retrenchment, lower costs, more healthy and saner business.

We are led to believe confidently that as a general average, prices are at the bed rock bottom. In some instances they are lower than wholesomely sound business principles demand. On the other hand, the automotive industry is the exception, in that it has not liquidated to the same extent that many other industries have. We are advised by an eminent economist that we have rounded the corner and are now entering that period which will tell largely who will be weeded out and who will remain as potential members of each industry.

It is obvious that the problems confronting the automotive industry as a whole, have undergone a great change during the past 18 months. From a sellers' market accompanied by rising prices, frenzied production and almost unlimited demand, we have passed to a buyers' market with its depression, falling prices, and insufficient demand in some cases to even run part time.

What readjustments can be made in the realm of production methods, designs, materials, heat treatments or methods of merchandising which will meet the changed market conditions, stimulate the demands for, and effectually increase the economic value of the automobile? These are the questions which may well engage the attention of the best minds among executives and engineers. It seems that upon the solution of such problems the future course of the automotive industry depends.

To readjust intelligently the methods of production, change designs, materials, heat treatments and many other practices with the idea in mind of lowering cost of production, thus effectually reducing the selling price of the car; it must be considered from the following standpoints:

1. Cost of such changes requiring new equipment, new layouts, new machines, etc.
2. Quality from the serviceability standpoint must not be sacrificed, however, unnecessarily high safety factors are to be discouraged.

Roger W. Babson states in a recent financial forecast that the automotive industry does not know what getting down to bed rock bottom means. This is no idle gossip when you consider the prestige Mr. Babson enjoys as an expert economist and statistician; consequently, you are not surprised that his forecasts are considered investment criterions by investment bankers and financiers.

It is hoped the automotive industry will not wait until its hands are forced, but that it may anticipate the problems to be solved and jump into the field at once. As an example we may quote a typical example of substitution:

1. Plain carbon steel for alloy steel where feasible.
2. Elimination of heat treatment where possible and practical.
3. Substitution of cast iron for aluminum, brass and bronze.

A paper presented at the January meeting of the South Bend Chapter. The author, V. A. Crosby, is foundry metallurgist, Studebaker Corp., South Bend, Ind.

Comment and Discussion

Papers and Articles Presented Before the Society and Published in Transactions Are Open to Comment and Criticism in This Column—Members Submitting Discussions Are Requested to Give Their Names and Addresses

DEPTH OF PENETRATION STATEMENTS CORRECTED

CONSIDERABLE discussion has been provoked by the paper "Efficiency of Different Mixtures for Cyanide Hardening and the Role of Nitrogen in the Process" by Victor E. Hillman, metallurgist Crompton & Knowles Loom Works, Worcester, Mass., appearing on page 296 of the January issue of TRANSACTIONS. Correspondence with the author has developed that the manuscript was in error in several instances as regard to the depth of the case. With these corrected as follows, most of the questions are answered. On page 297, the last part of the fifth line from the bottom of the page should read "amounts to approximately 0.004 inch." The first part of the last line on this same page should read "to a depth of 0.007 inch." On page 298 the ordinates of the curve should read .001, .002, .003 up to .012 instead of .01 up to .12. The caption Fig. 4 on page 301 should read "Micrograph showing the appearance of the case, which is 0.0054-inch deep."

CYANIDE DATA SEEMS CONFUSING

IN TRANSACTIONS for January V. E. Hillman says on page 303 that "Various investigations have analyzed the case formed in cyanide hardening and found that the carbon content varies from 0.03 to 0.06 per cent. Under conclusions he states that "1. Cyanide hardening is poorly adapted for deep cementation."

On page 304, G. R. Brophy at the last says, in speaking of carbon per cent in the cyanide case. "We never found it as high as 0.60 per cent."

In the article by R. L. Dowell on page 320 one gains the impression that cyanide is used to cement steel to 1/16-inch depth and often much deeper and that in one instance the carbon at the center of the gear teeth was 0.75 per cent.

There have been numerous articles on cyanided work, its action, analysis of case, etc., there are however, instances such as noted above that cause confusion.

Recently one of my associates analyzed a rod taken from a cyanide basket which had been in use for at least two months. Originally this rod was mere screw stock. The carbon per cent determined was 2.74. The nitrogen was high but of course could not be compared with the original content. The material was with difficulty machined in the annealed state. The fracture was that of tool steel.

It is hoped that a solution to these varied observations may soon clear up the confusion.

STANLEY P. ROCKWELL, Metallurgical Engineer,
65 Highland Street, Hartford, Conn.

FURTHER REMARKS ON CYANIDE HARDENING

DISCUSSION of paper by V. E. Hillman on Cyanide Hardening, which appeared on page 296 of the January issue of TRANSACTIONS.

Results of researches at the General Electric Co.'s research loboratories on cyanide hardening were reported before the Society in September, 1920, and were published in TRANSACTIONS in March, 1921. It was shown that nitrogen combined in some manner with iron with extreme hardness and brittleness resulting when the metal was quenched. The depth of penetration was as great after 15 minutes as was the case after one hour. Even a four hour immersion gave no appreciable increase in total depth of penetration, but it was shown that the concentration, as indicated by the amount and width of the patch layer increased with exposure. The depth of penetration was estimated by the distance from the surface to the innermost needle.

Analyses of the metal immediately on the surface of cyanided rods gave at best but 0.33 per cent carbon, not sufficient to account for the hardness obtained. The rods were of pure iron containing no carbon, so that any carbon present after treatment was introduced by the cyanide. Commercial sodium cyanide was used at a temperature of 800 degrees Cent. Under actual abrasive test cyanided parts showed but one-fifth the life of carburized parts, and when subjected to impact, failure was immediate.

In the present article the author, it appears, has not sufficient experimental evidence to support a number of his statements. His repeated assertion that cyanide exerts a carburizing action is in error, in view of his own and other investigator's results. Nitrogen is the hardener and not carbon. However, the increased carbon content of his cases and the difference in penetration may be due to the fact that his bath is made up of Na_2CO_3 plus NaCN.

When Na_2CO_3 is melted it is a well known fact that CO_2 is liberated also that NaCN is an active reducing agent. Therefore, is it not possible that CO_2 is reduced to CO with the formation of NaOCN, and the steel carburized by the CO? If this is true, then Na_2CO_3 is not inert as the author states. If this is not true, then the curves for penetration of N_2 are evidently in error in the light of recent researches. More work would have cleared these points and until that is done the statements should not be set down as truths.

The composition which the author gives for the gases above his bath is questionable as regard to Na_2CO_3 and NaCN decomposing and to NaOCN. The length of time of exposure to ammonia gas and cyanide to produce the structures seem very long. A few hours in NH_3 at 700 degrees Cent. is sufficient to produce deep cases, and from 15 to 30 minute is sufficient in cyanide.

A point of interest which the author has not mentioned is that the needle form of nitrogen has not the hardening power of the patch forms which represents a higher concentration. It is the patch area, or depth of hardness, which changes on increased exposure and not the total penetration. Diffusion of this patch zone, however, does take place to some extent on subsequent annealing and heat treatment.

The author's curves should show less penetration than other researches describe, for it is proved that increasing carbon prevents penetration and lowers concentration of nitrogen. When high carbons are used both pearlite and the nitride loose their characteristic structures, each appearing to put the other in solution.

Samples of 0.002-inch pure sheet iron were heated in NaCN for several

hours to convert them to 100 per cent nitrogen compound. These were then analyzed by the Allen method, which the author says gave good results, and practically no nitrogen was found. This would indicate that the dark patch and needle constituent are other than nitride of iron. Doctor Fay, of Massachusetts Institute of Technology, recently has been working on a method for the determination of N_2 in steel and promises some interesting data shortly.

We have shown recently that C is not necessarily present in the patch. Cases obtained by heating in pure NH_3 show this constituent, but perhaps not to the extent that it occurs in cases obtained from commercial gas. The term "Flavite" given to this patch constituent by Mr. Hillman, is a new one, not having been used in previous publications, and should be put forth as tentative until approved generally.

G. R. BROPHY, Research Metallurgical Engineer,
General Electric Co., Schenectady, N. Y.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment—Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions.

QUESTION NO. 5. What is needle bar stock?

QUESTION NO. 6. Does the temperature in the carbonizing box or pot at any time become greater than that of the furnace in which it is being heated?

QUESTION NO. 7. May tools be heat treated properly in a furnace in which copper is present?

QUESTION NO. 8. What is the effect of high and low silicon in tool steel?

QUESTION NO. 9. In carbonizing does not the carbon increase slightly even in the core section?

QUESTION NO. 10. What surface of steel, that is, machined, cold rolled, hot rolled or cold drawn, carbonizes fastest and why?

QUESTION NO. 11. Has high speed steel ever been carbonized and if so what were the results?

QUESTION NO. 12. How and why is cast iron heat treated? Is there such a process as ageing or seasoning castings other than by annealing?

QUESTION NO. 13. A swaging die for tubing receives 3600 blows per minute. It has been found that a scleroscope hardness of about 95 is necessary to prevent excessive wear. When this hardness is obtained considerable trouble is encountered in warping during heat treatment. Is there any steel in which this hardness can be procured without warpage?

QUESTION NO. 14. What can be done to prevent coiled strip stock from sticking together when annealed? This stock is bright rolled, wound into coils and pack annealed and the coils sometimes stick together. It cannot be softened by heating below the critical range for fear of grain growth due to critical straining.

QUESTION NO. 15. Is it possible to obtain, commercially, the following physical properties in the heat treatment of 3-inch forgings made of chrome nickel steel according to the S. A. E. specification No. 3130, selecting the test bar one-half way between the center and the outside of the forging:

Elastic limit pounds per square inch	Tensile strength pounds per square inch	Elongation per cent	Reduction of area per cent	Scleroscope hardness
115,000	140,000	17.5	63.0	40

Chemical Composition

Carbon per cent	Manganese per cent	Phosphorus per cent	Sulphur per cent	Nickel per cent	Chrome per cent
0.25—0.35	0.50—0.80	not over		1.00—1.50	0.45—0.75
0.30 desired	0.65 desired	0.04	0.045	1.25 desired	0.60 desired

ANSWER. It is not commercially possible to obtain the above physical properties on a steel of this composition, using a 3-inch section and selecting the test bar one-half way between the center and the outside of the forging.

It would appear that in selecting this specification from the "Physical Characteristics" chart of the S. A. E. for this steel, there has been some confusion. The figures for elongation, reduction of area and scleroscope hardness correspond to the chart for a 900 degree Fahr. drawing temperature, while the elastic limit corresponds to that for an 800 degree Fahr. drawing temperature and the tensile strength to that between an 800 and 900 degree Fahr. draw.

It is obvious that such a combination cannot ordinarily exist. Furthermore the physical properties as given in this chart have been obtained in the heat treatment of ½ to 1½-inch round specimens. Therefore they would not apply to forgings 3 inches in diameter, with the test bar selected half-way from the center to the outside. The cooling time in quenching the larger section is too great to permit the retention of the more unstable higher strength constituents.

Even the problem of obtaining these physical properties on a small sized section would be quite vexations to the heat treater. As a commercial proposition it would be even more troublesome. When the larger sections are involved it is safe to say that these properties cannot be obtained.

Unfortunately there is little information available on the physical properties which ordinarily can be obtained in the heat treatment of this class and composition of steel of a 3-inch section, with the test bar selected from midway between the center and the outside of the section. The following tabulation gives a resumé of some results obtained from various sources in the literature and it can be seen that in no case has this specification been reached, in spite of the fact that thesec tions have been small. Specimen No. 16 meets this specification, but is a chrome vanadium steel 1-inch in diameter.

Specimen No.	Diameter inches	Elastic limit pounds per square inch	Ultimate Strength pounds per square inch	Elongation per cent	Reduction of area per cent	Scleroscope hardness
1	1	125,000	137,000	22.0	62.0	
2	1	138,000	150,000	20.0	58.0	
3	1	160,000	178,000	17.0	53.0	
4	1	133,000	162,000	16.0	57.0	
5	1	158,000	175,000	13.0	53.0	
6	1	115,000	142,000	17.0	59.0	
7	1	150,000	165,000	18.0	55.0	
8	1	110,000	140,000	19.0	60.0	
9	1	110,000	140,000	18.0	50.0	
10	1	115,000	140,000	18.0	52.0	
11	1¼	118,000	132,000	21.5	63.0	44
12	½	120,000	141,000	17.0	57.0	42
13	1¾	121,000	138,000	21.0	60.0	40
14	1⅞	116,000	137,000	17.0	60.0	40
15	3¼	106,000	130,000	18.0	56.0	38
16	1	123,000	141,500	18.0	63.5	

The chemical analysis of the above metals with their treatment is given below. These results were the nearest that could be found which in any way seemed to approach the specification of the original question.

Specimen No.	Carbon per cent	Manganese per cent	Chromium per cent	Nickel per cent	Quenched degrees Fahr	Drawn degrees Fahr
1	.28	.49	.63	1.79	1475	1100
2	.28	.49	.63	1.79	1475	1000
3	.28	.49	.63	1.79	1475	800
4	.37		.42	1.35	1430	900
5	.37		.42	1.35	1430	800
6	.37	.55	.42	1.35	1430	1000
7	.28	.49	.63	1.79	1475	900
8	.40		1.00	2.00	1425	1100
9	.50		.50	1.25	1425	1075
10	.40		.75	3.00	1450	1050
11	.40		70	1.31		1000
12	.40		.70	1.31		1000
13	Low nickel chrome. Exact analysis not given.					
14	.19		.90	3.50	Treatment not given.	
15	Low nickel chrome. Exact analysis not given. Treatment not given.					
16	.26	.48	.92	.20*	1650	1020

* Vanadium

QUESTION NO. 16. Does acid pickling cause brittleness in steel by widening the grain boundaries? How can pickle brittleness be removed?

ANSWER. This question was perhaps prompted by an article by C. J. Morrison, which appeared in *Iron Age* in August of this year. In this article evidence is presented which is claimed to show that the embrittling action of pickling is due to an eating out of the grain boundaries in steel. The evidence consists in three micrographs representing the following conditions: 1. Normal steel before pickling; 2. Steel made brittle by pickling; and 3. Steel made brittle by pickling and restored by heat treatment. In these micrographs the grain boundary lines appear widest in the brittle material and of less but about equal width in the other two samples. Measurements are given stating that the grain boundaries are about three times as wide in the brittle steel as in the others and it is concluded that the cause of pickle brittleness has been proved by this work.

In a later issue of *Iron Age* there is a discussion of this article by George Comstock of the Titanium Alloys Co., in which the conclusion reached in the above article is severely criticized. Comstock contends that the reason for the greater apparent width of the grain boundaries in the second micrograph is that the photograph was taken out of focus.

The writer believes that Comstock's criticism is justified inasmuch as all of the micrographs were somewhat out of focus and were poor in other respects. Pickle brittleness cannot be attributed to widening of the grain boundaries on the basis of the evidence given in this article. This does not mean necessarily that a selective attack on the grain boundary material by the pickling acid is not a factor in causing the brittleness.

It would be important to establish whether the fracture follows the grain boundaries in steel which has been made brittle by pickling. If it does not, then brittleness cannot be attributed to this cause. If it does follow the grain boundaries, brittleness can be attributed to some grain boundary condition which may or may not be a widening caused by corrosion. In looking for information on this point, I have found that most of the people

who have had experience with this difficulty have not observed the path of rupture. One metallurgist says, however, "furthermore the brittleness caused seems to be an intercrystalline one, that is, the fracture seems to follow the grain boundary."

J. V. Emmons has suggested that the brittleness may be due to a notch effect consisting in the formation by the pickle acid of minute grooves or notches on the surface of the steel especially at the grain boundaries. This would cause the metal to begin to tear at the grain boundaries. The suggestion is quite logical inasmuch as it is well known that even very light scratches on the surface of steel sheet seriously impair its cold working properties.

If the idea of surface notches is correct then the brittleness should be confined chiefly to the surface of the metal and should disappear after the surface layer is removed. There are many indications that pickle brittleness is a surface phenomenon. To begin with it is practically unnoticed except in material of small cross section chiefly sheet and wire. This may be explained in part by the fact that heavier sections such as bar stock and steel forgings are as a rule not subjected to any deforming process, which would reveal brittleness even if it exists. Steel sheet and wire are especially apt to show up this defect, because of the severe deformation they are subjected to in fabrication.

W. C. Main states that pickle brittleness can be removed by taking off a very thin layer from steel sheet, perhaps not over about 0.003 inch. This certainly indicates that the surface layers are at least the most affected, which is bound to be the case since the acid begins its attack on the surface. Opinions have also been expressed that brittleness permeates the entire cross section, especially in the case of sheets. The truth of the matter is probably that the action is similar to that of carbonizing, beginning at the surface of the metal and penetrating to a greater depth the longer the pickling is continued.

There is general agreement that this type of brittleness can be removed readily by heating and a common heat treatment seems to be about 10 hours at 400 degrees Fahr. It has also been brought out that no trouble is encountered from pickle brittleness when the metal is heated in the natural course of fabricating operations after the pickling process. This applies to material which is heated for hot rolling or annealing or which is galvanized.

The orthodox theory is that the brittleness is due to the absorption by the steel of the hydrogen liberated in the pickling process. The removal of brittleness by heating is then supposed to be due to the expulsion of hydrogen. If we accept the "notch theory" of brittleness than we must find some other explanation of the removal of brittleness by heating. Mr. Emmons has suggested that this is due to the removal of a small amount of metal by oxidation thereby rounding the corners of the notches or removing them altogether. It appears, however, that pickle brittleness can be removed by heat treatment at a temperature so low that no visible oxidation occurs, and even disappears slowly when the steel is allowed to stand or age at ordinary temperatures. This can be explained on the basis of a slow loss of absorbed hydrogen, but it is difficult to explain on the basis of removal of notches from the surface.

It is still more difficult to account for the restoration of ductility if we consider that the brittleness is due to the actual removal of grain boundary

metal. The most that we can concede the grain boundary theory is that the grain boundaries are particularly affected either because of a local penetration of hydrogen or because of the notch effect mentioned.

In connection with this question the writer has made some inquiries as to the prevalence of pickle brittleness and found that the largest producers of material in which this defect might be expected do not seem to have much trouble with it. One large company reports that much of its product is not heat treated subsequent to pickling and is subjected to severe deforming operations by customers without any difficulty. It is to be expected that the effect of the brittleness developed will depend considerably on the pickling conditions. Some alternating bend tests by Prof. H. O. Arnold on steel bars showed that doubling and trebling the time of pickling continuously decreased the toughness of the steel. It seems, therefore, that if proper care in pickling is exercised and especially if some time elapses between pickling and use, brittleness is the exception rather than the rule.

QUESTION NO. 17. For some time past we have been water quenching steel castings in order to improve their physical properties. These castings are mostly shrouded pinions and plain rollers, weighing from 150 to 500 pounds each. These pieces would be immersed in the water bath for a short period of time, usually from one to two minutes and then withdrawn and allowed to cool in the air. Our results have been satisfactory but we feel that we can improve this method somewhat by a slight modification in the treatment. In order to relieve cooling strains, one suggestion is that we provide a tank filled with infusorial earth in which the castings would be placed in order that cooling might be slow and uniform. Another suggestion is that instead of using a plain water bath, we introduce sodium hydrate in order that the quenching may not be quite so severe. We would like to know which of the above plans would be the better or if there is any other better plan which could be suggested. We do not care to use oil because of its expense.

NOTE. Rollers may break in the flange a month or more after above treatment. Loss at present is 2 per cent. Pinions, after above treatment, are drawn in furnace to 1200 degrees Fahr. for toughness. If drawn shortly after quenching there is no trouble, but this is not always practicable when working day turn only. If allowed to stand in air after quenching, cracking may result, hence the suggestion for covering with infusorial earth or ashes. We have had only one batch to show cracks.

QUESTION NO. 18. What is the relationship between Brinell and Scleroscope hardness?

QUESTION NO. 19. What is the shortest time in which malleable castings can be annealed to produce the best malleable qualities?

QUESTION NO. 20. What are the causes of warping in the heating and cooling of steel?

QUESTION NO. 21. In answering Question No. 3, which appeared in the January issue of TRANSACTIONS, *C. Craine, Mattison Machine Works, Rockford, Ill., refers to the fact that cast iron gage bases were treated at temperature from 600 to 900 degrees Fahr. for a period of 12 to 18 hours, and were allowed to cool in the furnace, the theory being that this treatment*

obviated the necessity for the ageing of the castings. What effect, if any, would have been produced had the castings been heated to a very much higher temperature, say 1600 degrees Fahr.? In view of the fact that certain of the castings referred to had to be twice re-treated in a similar manner for 12 to 24 hours, before overcoming all effects of warpage, the value of the treatment seems doubtful. What assurance is there that some of the castings which were treated but once, ought not to have been treated twice, or even three times?

ANSWER. By H. A. Schwartz, manager of research, National Malleable Castings Co., Cleveland. Any casting develops internal stresses due to unequal cooling and retains its final shape due to a balance between opposing internal stresses. On machining off stresses material, the equilibrium is disturbed and the casting warps. Ageing, heating, vibration or the removal of metal with light cuts on opposite sides all serve as a means of slowly relieving internal stresses and hence of preventing warping on subsequent machining. It would seem that to be effective as an eliminator of casting strains, the temperature reached in heat treating must be sufficiently high to cause a distinct increase in ductility of the iron. Such an increase is not observed until the metal is heated above 900 degrees Fahr., but the increase in softness with increasing temperature above 900 degrees Fahr. is very rapid. Any temperature above 1400 degrees Fahr. if maintained sufficiently long will cause a resolution of the graphite with possible increase of hardness unless cooling is very slow. At temperatures as high as 1600 degrees Fahr. the metal, if it contains graphite, must be protected from oxygen, or carbon dioxide, else these gases will oxidize carbon, penetrate into the metal first where the graphite was and later along the grain boundaries, oxidize the metal and produce a "rotten" product. In any event the cooling of the metal must be uniform throughout and quite slow.

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Heat Treaters

By H. E. Gladhill

CHROME STEEL

CHROMIUM STEELS AND IRON. By Leslie Aitchison, *Engineering*, Vol. CXII, Pages 771 and 805.

The properties required of an alloy steel for use in automobile parts are described and it is shown that chromium steels fulfill the requirements in a fair measure. Three per cent chromium is recommended for heavy work while 1 to 1.5 per cent is sufficient for small parts. The proportion of carbon in the steel exercises a greater influence than does the chromium on the physical properties. Stainless irons are recommended for their ease in working. Vanadium is not found to benefit chromium steels.

FORGING AND HEAT TREATING EXPERIMENTS

FORGING EXPERIMENTS WITH MILD STEEL. By P. J. Junkers, *Forging and Heat Treating*, Vol. 7, Pages 518 and 553.

Tests were made on 0.13 and 0.50 per cent carbon steels. Forging the 0.13 per cent carbon steel below 750 degrees Cent. raised the breaking strength and elastic limit. Forging above 750 degrees Cent. lowered these properties. With the 0.50 per cent carbon steel, the improvment in properties due to forging was greater than in the case of the 0.13 per cent carbon steel. Photomicrographs illustrating the effect of forging on structure are shown.

ON THE HEAT TREATMENT OF ALUMINUM BRONZE. By A. A. Blue, *Chemical and Metallurgical Engineering*, Vol. 25, Page 1043.

Marked changes in the hardness of the 90 per cent copper, 10 per cent aluminum alloy may be produced by heat treatment. The tensile strength and yield point, however, are little affected by heat treatment or by forging. Difficulty is encountered in obtaining uniform results with the cast alloy. Published data on the physical properties is not duplicated under practical working conditions.

INFLUENCE OF PHOSPHORUS UPON MICROSTRUCTURE AND HARDNESS OF LOW CARBON STEELS. By E. C. Groesbeck, Bureau of Standards, Technologic Paper No. 203.

Heat treatments were run on acid and basic open-hearth, low carbon steels containing varying amounts of phosphorus. The Brinell hardness was found to increase slightly with increase in phosphorus. No relationships were found between phosphorus content and grain size and phosphorus content and scleroscope hardness. A peculiar cellular-like structure was noticed and its relation to the phosphorus distribution established.

HIGH SPEED AND CARBON TOOL STEEL

HARDNESS OF HIGH SPEED STEEL. By A. H. d'Arcambal, *Chemical and Metallurgical Engineering*, Vol. 25, Page 1168.

Experiments made on 15 samples showed that so far as uniform structure and good cutting properties are concerned the best heat treatment for high speed steel was quenching in oil from 2300 degrees Fahr. and drawing 1100 degrees Fahr. Quenching the steel into a bath at 1100 degrees Fahr. and air cooling without drawing did not give the same good results as were obtained by drawing the quenched tool at 1100 degrees Fahr. High speed steel in large rounds is seldom free from carbide and tungstide segregation. Tools made of this material were inferior to those made from material having been given a greater reduction in cross section.

Neither scleroscope nor Brinell hardness were found to be indicators of cutting quality.

VARIOUS METHODS FOR HARDENING HIGH SPEED STEEL. By A. H. d'Arcambal, *Chemical and Metallurgical Engineering,* Vol. 25, Page 1150.

Salt and lead bath hardening, pack hardening and semimuffle furnace hardening are described and their advantages and disadvantages discussed. The first three reduce the amount of scaling but in general give too low a quenching temperature for best results. The last method is the one most used in this country.

AMERICAN PRACTICE IN HIGH SPEED STEEL MANUFACTURE. By A. H. d'Arcambal, *Chemical and Metallurgical Engineering,* Vol. 25, Page 1097.

The information contained in this article was obtained as a result of visits to eight of the largest tool steel mills in the country. Crucible practice was used at six of the mills, the electric furnace being used for melting at the two remaining plants. In general, muck bar is used as a base for high speed steel. Considerable diversity of opinion exists as to the proper materials for fluxing, etc., in electric furnace practice. "Hot top" casting practice generally is used. The ingots are hammered into billets and the billets are reduced by rolling or hammering. Photomicrographs are shown of the steel at the various stages.

NOTE ON MUSKET STEEL. By A. H. d'Arcambal, *Chemical and Metallurgical Engineering,* Vol. 25, Page 1055.

Three heat treatments were made on samples of musket steel. The steel contained 2.38 per cent carbon, 1.12 per cent chromium and 4.80 per cent tungsten. Quenching from 1900 degrees Fahr. and drawing at 1000 degrees Fahr. give the best structure.

HEAT TREATING OF TOOL STEELS. By L. A. Lanning, *Blast Furnace and Steel Plant,* Vol. 9, Page 706.

The tests were made on 1.10 per cent carbon tool steel in the form of cylinders. The effect on dimensional changes of various heating up rates, hardening temperatures, quenching media and tempering temperatures was determined. The data is presented as curves.

METALLOGRAPHY AND HARDNESS THEORY

PRESENT THEORIES OF CARBURIZING STEELS. By H. B. Knowlton, *Forging and Heat Treating,* Vol. 7, Page 543.

The iron-carbon diagram is explained and the carbonizing reaction is described. The effect of single and double heat treatments on carbon distribution, grain size and hardness is discussed and illustrated by numerous photomicrographs.

ON THE THEORY OF THE HARDENING OF METALS. By K. Honda, *Chemical and Metallurgical Engineering,* Vol. 25, Page 1001.

The "slip interference" theory of Jeffries and Archer is discussed. Honda considers hardness to be due in part to interatomic forces and in part to an interlocked crystal structure.

STRAIN LINES IN LOW CARBON STEEL. By A. Fry, *Iron Age,* Vol. 108, Page 1401.

The use of a macroscopic etching reagent consisting of, water 100 cubic centimeters, concentrated hydrochloric acid 120 cubic centimeters and copper chloride crystals 90 grams is described. The sample of steel must be given a short low temperature anneal before it is affected by the reagent. Strained low carbon steel is the only ferrous product the reagent has given results on thus far.

ACTION OF INTERNAL STRESS ON TOOL STEEL. By C. N. Greenwood, *Forging and Heat Treating,* Vol. 7, Page 560.

The possible origin of initial stresses in metals and alloys are examined. Cold working and suppression of phase changes are the two main causes. The later factor is developed in some detail. Manganese and chromium are recommended for reducing strains due to quenching. No new data is presented.

ELEMENTS OF THE HEAT TREATMENT OF STEEL. By H. J. French, *American Machinist,* Vol. 55, Pages 907 and 960.

Heat treatment is classified as being made up of the following operations: (1) Normalizing and annealing, (2) hardening, (3) tempering, (4) seasoning and (5) case hardening. The structural and physical property changes brought about by these operations are described and illustrated by photomicrographs, curves and tables of data.

PHYSICAL TESTS

PHYSICAL TESTING LABORATORIES DESCRIBED. By G. F. Comstock, *Forging and Heat Treating,* Vol. 7, Page 549.

A plan, view and brief description of the Titanium Alloy Mfg. Co.'s laboratory is given. The laboratory is housed in a long, narrow, well-lighted brick building.

SCLEROSCOPE HARDNESS OF STEEL BALLS. By A. L. Collins, *Iron Age.* Vol. 108, Page 1391.

With a series of balls held in the usual way on the anvil of a scleroscope, readings which are very apparently incorrect are obtained. Experiments showed that the difference in the curvature was not responsible for the irregularities. Imbedding the balls in soft solder in blocks of special design eliminated the difficulties giving uniform readings for all sizes of balls.

OXIDES AND SULFIDES IN ORDNANCE STEEL. By W. J. Priestly, to be presented at the February, 1922 meeting of the Institute of Mining and Metallurgical Engineers.

It is shown by photomicrographs, analyses, and physical tests that properly made duplex electric steel is superior to straight open-hearth steel. Methods of steel production in the various ordnance plants during the war are discussed.

ENDURANCE OF STEEL UNDER REPEATED STRESSES. By D. J. McAdam Jr., *Chemical and Metallurgical Engineering,* Vol. 25, Page 1081.

Data from a very extensive series of tests is presented in an endeavor to correlate endurance stresses with other physical properties. The endurance tests were made on a modified White-Souther machine. Carbon steels running from 0.13 to 0.77 per cent carbon as well as 14 of the common alloy steels were tested. Curves of endurance test results on logarithmic or semilogarithmic paper showed no abrupt change of direction throughout the cycle range investigated. No relationship between endurance stress for 100,000,000 cycles and the corresponding proportional limit was found. A relationship does not exist, however, with the ultimate tensile stress. The ratio of endurance stress to Brinell hardness and to maximum torsional stress were found to be quite uniform. No relationship was found between the results of impact tests and endurance tests.

WELDING AND CUTTING

EFFECT OF OXYHYDROGEN CUTTING ON LOCOMOTIVE RODS. By A. F. Pitkin, *American Machinist,* Vol. 55, Page 964.

Blocks were cut from slab forgings, used for locomotive main rod forgings. Chemical analysis and metallographic inspection showed the heating effect of the cutting to be negligible on the remainder of the cut forging.

STEEL PLANT MAINTENANCE BY AUTOGENOUS WELDING. By Walter Petry, *Association of Iron and Steel Electrical Engineers,* Vol. 3, Page 555.

Important points and new developments in the use of the thermit, acetylene and electric arc welding processes are given. The thermit weld is in general better for heavy sections. For thin sections of cast iron gas welding generally is best. Most steel welds are best made by the electric arc processes. Examples of the use of welding methods in the steel mill are given.

NEW MEMBERS' ADDRESSES OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J. represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

BARR, HARRY L., (M-11), Follansbee Bros. Co., Follansbee, W. Va.
BECKER, M. E., (A-11), 299 Winsor Ave., Hartford, Conn.
BENTLEY, WM. P., (M-12), 2384 E. Grand Blvd., Detroit, Mich.
BODINE, FRANK, (M-1), 2303 14th Ave., Rockford, Ill.
BREELER, WALTER R., (C-1), 11610 Scottwood Ave., Cleveland, O.
BROWN, L. F., (M-11), Whitinsville Spinning Ring Co., Whitinsville, Mass.
BROWN, L. N., (M-1), 717 Southfield Rd., Birmingham, Mich.
CONWAY, F., (M-12), 121 Fourth Ave., Schenectady, N. Y.
COYLE, HARRY F., (M-12), Interstate I. & Steel Co., 118th & Calumet R. Rd., S. Chicago, Ill.
CRAIN, C. R., (M-11), Mattison Machine Works, Rockford, Ill.
CULLEN, JOHN F., (M-1), 498 Delevan Ave., Buffalo, N. Y.
DUNN, H. EARL, (M-11), 40 N. Emily St., Crafton Sta., Pittsburgh, Pa.
EKSTROM, E. S., (M-1), Mechanics Machine Co., Rockford, Ill.
EMERSON, R. L., (M-1), Waisner Mfg. Co., Rockford, Ill.
ERICKSON, JOHN E., (M-1), 1121 Revell St., Rockford, Ill.
FAUST, L., (M-1), Mechanics Machine Co., Rockford, Ill.
FIAT, (Sb. 10), Societa Anonima—Torino, Sezione Ferriere Piemontesi Via Caserta, 63-65, Italy.
FREER, W. G., (M-1), 516 Ave. B., Schenectady, N. Y.
GIBNEY, JAS. L., (M-1), 461 Woodward Ave., Buffalo, N. Y.
HENRY, A. W., (A-1), 209 Security Bldg., St. Louis, Mo.
HIDES, HORACE C., (A-1), Thos. Firth & Sons Inc., 1512 American Industrial Bldg., Hartford, Conn.
HILLMAN, SWAN, (M-1), 1704 6th St., Rockford, Ill.
JOHNSON, GEO. J., (M-1), 810 Kishawaukee St., Rockford, Ill.
KELLY, JAS. A., (M-1), 248 Lincoln St., Worcester, Mass.
KINGSLEY, M. W., (A-1), Elks Club, Detroit, Mich.
KOEHLER, CARL F., (M-12), 496 Fourth St., Struthers, O.
KOONMAN, EDW. A., (M-1), 1001 24th St., Watervliet, N. Y.
LANG, H. O., (M-1), Standards Dept. Oakland Motor Car Co., Pontiac, Mich.
LARSON, L. E., (M-1), 3918 Fir St., Indiana Harbor, Ind.
LINDALE, A. W., (M-1), 119 Unger Ave., Buffalo, N. Y.
LUNDSTROM, M. T., (M-1), 1211 Charles St., Rockford, Ill.
McDONALD, HENRY C., (M-1), 304 S. Fairmount Ave., Pittsburgh, Pa.
McGREGOR, HARRY, (M-1), 1124 Detroit St., Flint, Mich.
MERRILL, GEO. P., (A-12), Geo. P. Merrill, 420 S. Jefferson St., Saginaw, Mich.
MILLER, W. S., (M-1), 94 Dunn Bldg., Buffalo, N. Y.
MITCHELL CLARENCE B., (M-1), 1361 Abbott St., Detroit, Mich.
POLHEMUS, J. E., (A-1), 1776 Lafayette Blvd., W. Detroit, Mich.
ROBERTS, JOSEPH H., (M-1), care Midvale Steel & Ord. Co., Nicetown, Philadelphia, Pa.
SAILER, FRANK, (M-1), 2807 W. 22nd St., Chicago, Ill.
SARGENT, JOHN F., (M-12), 300 Ward St., Wallingford, Conn.
SHELAIN, FRANK, (M-1), 422 So. 2nd St., Rockford, Ill.
STATES, W. J., (M-11), 100 Howard Ave., Altoona, Pa.
STEWART, M. G., (S-1), Box 276, Shreveport, La.
STIVERS, LEONARD C., (Jr. M.), 715½ W. 4th St., Davenport, Iowa.
SWANSON, C. S., (M-1), 8127 Harper Ave., Chicago, Ill.
SWENSON, L. G., (M-12), 2963 Vicksburg Ave., Detroit, Mich.
TAYLOR, LEON E., (M-1), 2127 6th St., Rockford, Ill.
VIGEANT, XAVIER, (A-1), 1336 W. Washington Blvd., Chicago, Ill.
WALK, ESTELL M., (M-11), 12147 Hawthorne Ave., Highland Park, Mich.
WARDLE, W. C., (M-12), 2060 Bridge St., Frankford, Philadelphia, Pa.
WEBSTER, A. C., (M-1), 903 W. Euclid Ave., Detroit, Mich.

CHANGES OF ADDRESS

ANDERSON, F. E.—from 117 Mitchell St., to 533 Mitchell St., Providence, R. I.
BEELER, C. F.—from 10117 Adelaide Ave., to 2066 E. 89th St., Cleveland, Ohio
BERGGREEN,—from Reck Heating Co. Ltd., 15 Esromgage, Copenhagen, to Berggreen & McConnell, 604 Oliver Bldg., Pittsburgh, Pa.
BULL, R. A.—from Sewickley, Pa., to Spondly Bldg., 639 Diversey Parkway, Chicago, Ill.
BROOKS, CHAS. A.—from Bethlehem Ship Corp. to 2139 Gilles St., Wilmington, Del.
CARLSON, C. A.—from 1532 Eleventh Ave., to 1414 14th St., Moline, Ill.
DISARIO, JOHN—from 10304 Union Ave., Cleveland, Ohio, to P. O. Box 122, Rocky River, Ohio.
DODGE, RALPH—from New Process Gear Corp., to 810 Park Ave., Syracuse, N. Y.
DESNER, RAYMOND—from 3055 Ruckle St., Indianapolis, Ind., to 1495 Elmhurst Ave., Detroit, Mich.
DOWNER, ALVIN C.—from 3737 McGraw, to 1179 W. Kirby, Detroit, Mich.
DOWNIE, P. C.—from 3117 12th St., to 17161 Sunset Ave., Detroit, Mich.
DEVINE, H. A.—from 218 E. 55th Pl. to 7316 Princeton Ave., Chicago, Ill.
EDWARDS, W. F.—from 13 Brownes Terrace, Englewood, N J., to U. S. Testing Co., Inc., 316 Hudson St., New York City.
EMERSON, DR. H. C.—from 83 Maple St., to 145 Chestnut St., Springfield, Mass.
FOWLER, H. R.—from 77 Everett St., to 43 Rougeley Rd., Arlington, Mass.
GIBLIN, RICHARD J.—from 1804 Proctor St., to Penfield Apts., 409 E. Kearsley St., Flint, Mich.
GRIGGS, HENRY L.—from The Bristol Co., Room 1004, Engineering Bldg., New York City, N. Y., to 139 E. 66th St., New York City.
JACKSON, WM.—from Dittmer Gear & Mfg. Co., to 574 Walnut St., Lockport, N. Y.
McBRIDE, A. F.—from 520 Seventh St., to 311 Beech St., Oakmont, Pa.
PERRY, HERBERT J.—from Rodman Chemical Co., Verona, Pa., to 815 Lake St., Racine, Wis.
PLATTS, J. C.—from 6A Fairfield Sq., Droylsden, Manchester, England, to Ashfield, Slade Grove, Longsight, Manchester, England.
PUSITZ, L.—from 5348 Russell, to 3514 28th St., Detroit, Mich.
RODNEY, KEITH R.—from Bullard Machine Tool Co., Bridgeport, Conn., to New Castle, Delaware.
ROWE, CHAS. O.—From Electric Alloy Steel Co., 511 Penna. Bldg., Philadelphia, Pa., to 330 W. Duval St., Germantown, Philadelphia, Pa.
SCOVEL, ALFRED J.—from D. O. James Mfg. Co., 1120 W. Monroe St., Chicago, Ill., to 5912 Grand River Ave., Detroit, Mich.
SIMMONS, C. P.—from Latrobe Elec. Steel Co., 165 Broadway, to 366 Madison Ave., New York City.
SHAW, G. M.—from 642 Munsey Bldg., Washington, D. C., to 1517 Continental Bldg., Baltimore, Md.
TORSELL, CARL T.—from The Warren Iron and Steel Co., Warren, Ohio, to 112 Dickey Ave., Warren, Ohio.
WEDLAKE, PERCY—from Washington Steel & Ordnance Co., Washington, D. C., to 125 Atlantic St., R. F. D. No. 8, Anacostia, D. C.
WESLEY, CHAS.—from 651 S. Pierce St., to 348 13th Ave., Milwaukee, Wis.
WHITE, W. H.—from Box 296 to 3 Washington St., S. Charleston, W. Va.
WILLIAMS, W. E.—from 3317 Rhodes Ave., Armour Sta., Chicago, Ill., to 504 Oakwood Blvd., Chicago, Ill.

MAIL RETURNED

BONNER, WM. T., Engr., New York Shipbuilding Corp., Camden, N. J.
EVES, ROBT. J., Erie Beach, Ont., Canada.
GEBERT, N. J., 717 W. Genesee St., Syracuse, N. Y.
GUSTAFSON, R., 1815 13th Ave., Moline, Ill.
PENROD, W. W., 1664 Waterbury Rd., Lakewood, Ohio.

News of the Chapters

SCHEDULE OF REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list should communicate with the National Office in order that the list may be as complete as possible.

Charleston—First Tuesday, Kanawah Hotel, 8 p. m.

Chicago—Second Wednesday, City Club, dinner 6:30 p. m., meeting 8 p. m.

Hartford—Thursday nearest 10th of month, Jewell Hall, Y. M. C. A., 7:45 p. m.

New York—Third Wednesday, Engineering Societies building, 29 West Thirty-ninth street.

Pittsburgh—First Tuesday, Chatham Hotel, dinner 6:30 p. m., meeting 8 p. m.

Rockford—Second Monday, Nelson Hotel.

Schenectady—Third Tuesday, Civil Engineering Bldg., Union College.

Tri Cities—First Thursday following first Monday.

Washington—Second Friday.

PHILADELPHIA CHAPTER

The Philadelphia Chapter held its postponed December meeting on Friday night, Jan. 6 at the Engineers Club. The speakers of the evening were Horace Drever, and Dr. W. M. Mitchell. Mr. Drever, who is engineer for the Electric Furnace Construction Co., presented an illustrated lecture on "Typical Electric Heat Treating Furnaces." This lecture was very interesting and was well received.

A new and important feature of the meeting was the illustrated talk by Dr. W. M. Mitchell on "The Crystalline Structure of Steel." This was the first of a series of short talks on the fundamentals of the heat treating art which will be given at each meeting for the benefit of the general membership. These talks will be very practical, not highly theoretical and are intended to explain and make clear to the ordinary every day users, the terms. methods an processes in common use. No one engaged in the treating of steel can afford to miss these practical talks, and Dr. Mitchell's paper created considerable discussion, and proved mutually beneficial to all.

The January meeting of the Philadelphia Chapter was held in the Engineer's Building on Jan. 27. H. J. Stagg, assistant manager of the Halcomb Steel Co., Syracuse, N. Y., addressed the chapter. Mr. Stagg's illustrated talk was one of the best that has been presented before the local chapter this year, and carried with it the valuable experience Mr. Stagg had while metallurgist for the Halcomb Steel Company before his promotion to assistant manager. Mr. Stagg's pleasing personality, his wide circle of acquaintances, as well as the high regard in which he is held as a metallurgist all contributed in making the meeting a notable success.

The second of the series of fundamental talks was given by Edwin H. Barker, of the A. H. Wirz & Co., Chester, Pa., on "Local Hardening of

Extruding Dies." Mr. Barker's paper was illustrated with lantern slides and proved to be very interesting and was exceptionally well received.

The local chapter is having a membership campaign which closes on the night of the annual meeting to be held on Feb. 24. Last year the annual meeting was one of the largest held by any of the local chapters, and the claim is put forth that this year's meeting will be larger and better than the last. The list of invited guests is quite imposing and it is expected that the entire membership will be represented and bring with them the new members they have secured during the drive. National President Gilligan will be present at that meeting and the chapter is anxious to prove to him that they still retain the pep they previously had, and that they have thoroughly disproved the idea held in some quarters that Philadelphia was asleep.

LEHIGH VALLEY CHAPTER

The Lehigh Valley Chapter held the third meeting of its series on the "Manufacture, Treating and Testing of Steel." George C. Lilly, superintendent of the treatment department, Bethlehem Steel Co., and a member of the excutive board of the Chapter, was the speaker at a meeting of the Lehigh Valley Chapter held in the Auditorium of the Easton Public Library, Jan. 9. Mr. Lilly gave an illustrated talk on "Heat Treatment."

This was the third meeting of the series of practical and elementary talks which the Chapter is conducting on the manufacture, treating and testing of steel. As announced in the January TRANSACTIONS, this meeting was to have embraced "Rolling Mill and Foundry Practice" but the committee was obliged to change its plans and Mr. Lilly, who was scheduled to talk at a later date, very graciously met the emergency.

Mr. Lilly's talk was a thoroughly practical one throughout. Fully 75 charts, diagrams and photographs were used to illustrate the many phases of the practical application of heat treatment. Mr. Lilly's practical interpretation of the theory of and the terms used in defining heat treatment was considered by those present to be the clearest and simplest which had ever been presented to them.

The results of many tests were shown giving the effects of different heat treatments upon the physical qualities of steel. Mr. Lilly spoke at considerable length on the factors affecting the quality of heat treated product, such as the influence of the forging operation, the time allotted for heating both for forging and treating, the effect of mass on the physical properties, etc. Mr. Lilly also illustrated and discussed some of the equipment such as various types of furnaces and quenching apparatus used in the application of heat treatment of large forgings. The talk throughout was true to the form of the series and gave those attending the meeting much valuable information which they could apply in their every day practice.

WASHINGTON CHAPTER

The January meeting of the Washington Chapter was held on Friday, Jan. 20 in the ball room of the Harrington Hotel. The paper of the evening was by T. Holland Nelson, steel works manager of the Henry Disston & Sons Co., Philadelphia, Pa. Mr. Nelson's subject was a comparison of American and English methods of producing high grade crucible steels.

High grade tool steel demands the greatest skill, experience and precise knowledge for its proper manufacture. The position of Sheffield in the history and development of steel is known wherever tool steel is used. By reason of his experience in America and abroad, the speaker was particularly

fitted to contrast the methods of producing crucible steel in the Sheffield district with that produced by the best American practice. A comparison of the English product, made in the clay pot in coke hole furnaces, with the Amerian product, made in the graphite crucible in regenerative gas furnaces, showed many striking differences. Interesting details of the materials used and compositions made were brought forth. The meeting was largely attended and proved of much interest.

CINCINNATI CHAPTER

The Cincinnati Chapter held its regular January meeting on Monday, Jan. 23 at the R. K. LeBlond Machine Tool Co.'s plant. President F. P. Gilligan was present and after an interesting talk on society affairs, presented a paper illustrated with lantern slides on the subject of "What Happens to Steel When You Quench It." This was the first opportunity many of the members had to become acquainted with Mr. Gilligan, and a very excellent turn-out greeted the president

SOUTH BEND CHAPTER

The December meeting of the South Bend Chapter was held on Dec. 13, in the Recreation Building of the Studebaker Corp. Cider, doughnuts, cigars and cigarettes were served. About 55 attended the meeting.

The meeting took the form of a general discussion. Slips of paper were passed to each person on which they were to write a question to be brought before the meeting. These were then read and a discussion followed. The questions produced a great deal of discussion which had to be limited to 15 minutes for each question. At the end of the discussion V. A. Crosby, metallurgist at the Studebaker foundry, read a short paper on "Reconnoitering in Automotive Circles."

One of the best meetings the South Bend Chapter has held for some time, considered from the point of interest, and discussion took place on Jan. 10 at the Y. M. C. A. building. William Finkl, of A. Finkl & Sons, Chicago, was the speaker of the evening, selecting the subject of "Die Blocks." He handled his paper in a most capable manner. The discussion lasted for two hours after Mr. Finkl had finished the presentation of his paper.

The next meeting will be held on Feb. 14 and will be addressed by President Gilligan.

HARTFORD CHAPTER

The February meeting of the Hartford Chapter was held in Jewell Hall on Thursday, Feb. 9. The principal paper was presented by A. H. d'Arcambal, metallurgist of Pratt & Whitney Co. Mr. d'Arcambal has made extensive investigations of the effects of variations in composition and heat treatment on the life of high speed steel cutting tools. These investigations were conducted for the purpose of determining the best composition and best heat treatment to be used for tools manufactured by the Pratt & Whitney Co. His talk was illustrated by lantern slides, and was very instructive.

At this meeting, specimens were distributed, to be heat treated for the March Contest Meeting.

Particular attention is being given at the present time to arrangements for the plant visitation on April 29 at the New Departure Co., Bristol, Conn. This meeting has been arranged through the courtesy of the Bristol company, and will consist of the inspection of the entire

manufacturing plant. The inspection will start a 9 a. m. and dinner will be served at the New Departure plant at noon, and the afternoon will be devoted to talks.

This meeting has been arranged through the efforts of the local chapter and will be considered as a joint meeting of engineering societies, under the auspices of the American Society for Steel Treating and the Hartford and New Britain Sections of the American Society of Mechanical Engineers. It is expected that all of the New England sections of the above societies will be represented.

The Heat Treating plant of the New Departure plant is as large and up-to-date as any plant in the New England section and the chapter is looking forward to this meeting being one of the most interesting as well as the most instructive that they have ever held.

The list of meetings for the remainder of the season is as follows:

MARCH 10:—Heat Treatment Contest. Everyone is invited to compete for the prize.
APRIL 13:—"The Characteristics of Tool and Alloy Steels," by Dr. John A. Matthews, President Crucible Steel Co., Pittsburgh.
APRIL 29:—9:00 a. m., Inspection of New Departure Co. Plant, Bristol, Conn., Courtesy of the New Departure Co. All New England Chapters of American Society for Steel Treating and American Society of Mechanical Engineers are invited.
MAY 11:—"The Inspection and Heat Treatment of Steel," by J. J. Curran, The Henry Souther Engineering Co., Hartford, Conn.
JUNE 8:—Annual Banquet. Speakers to be announced later.

In addition to the subjects announced above, some time will be devoted each evening to:

1. "Question Box;" 2. Short reviews from current literature on steel treating and equipment; and 3. Some unique heat treatment effects observed by members.

SCHENECTADY CHAPTER

The December meeting was held on Dec. 20 at the regular meeting place, the Civil Engineering building, Union College. A paper was presented by W. E. Ruder, metallurgist, General Electric Co., on the subject of "Fatigue of Iron and Steel." About 55 members and guests were present, and enjoyed Mr. Ruder's presentation of this subject very much, and they also participated actively in the discussion. Special singing and moving pictures served as the entertainment of the evening.

The January meeting was held on the 17th when President Gilligan paid his annual visit to the chapter and presented a very interesting paper. Secretary Eisenman was also present and gave a few remarks with reference to the progress of the National Society. Moving pictures, through the courtesy of the General Electric Co. were also shown.

The Schenectady Chapter has issued a very fine little folder giving the dates and subjects of their meetings throughout the year, as well as a list of their chapter officers and the executive committee.

NEW HAVEN CHAPTER

The regular monthly meeting of the New Haven Chapter was held on Wednesday evening, Jan. 25 at the Hammond Laboratory, Yale University. This consisted of the inspection of the excellent equipment of the laboratory as well as a few short practical talks.

Much interest is being aroused by the prospect of a night course in metallurgy to be given at Yale University during the coming fall and winter, under the auspices of the Hammond Laboratory and with the cooperation of the New Haven Chapter. Professors Mathewson and Phil-

lips of Yale are working on the course in co-operation with the following committee appointed from the chapter: Fred Dawless, Chairman; members: Major A. E. Bellis, Walter Aurand, James Black and James Dunlevy.

TRI CITY CHAPTER

One of the best meetings the chapter has held for some time was that in honor of the official visit of National President Gilligan. Quite a large number attended the dinner held in the Davenport Chamber of Commerce on Jan. 26. In addition to President Gilligan's illustrated talk, motion pictures showing the manufacture of steel for sheets and plates were given through the courtesy of the Bureau of Mines.

CHICAGO CHAPTER

The January meeting of the Chicago Chapter was held at the City Club on Jan. 11 when over 100 members and guests participated in a practical discussion upon a number of very interesting subjects. Many of the questions brought up are published in the Question Box in another section of this issue of TRANSACTIONS. President Gilligan will be the speaker for the February meeting to be held at the City Club on the 9th.

The following announcement issued by the Lewis Institute is of special interest to members of the Society.

The department of mechanical engineering of Lewis Institute announces the following evening courses covering subjects of interest to members of the Society. Applications should be filed at once, preferably by Feb. 1. Applications received after the quota has been filled will be placed on the waiting list. Sessions begin on Monday and Tuesday, Feb. 6 and 7, and continue, two evenings per week, for 15 weeks.

3B-Heat Treatment of Steel—A lecture and shop practice course embracing: A study of the iron-carbon diagram; the effect of heat and work on the crystalline structure of steel; methods of selecting different grades of steel; methods of measuring temperatures and of calibrating pyrometers; critical temperature and how determined; theory of forging and effect of improper methods; purpose of annealing; hardening, grain refining, quenching, tempering, drawing; methods of case hardening; causes of warping and cracking of hardened steel pieces; testing for hardness and other physical properties; treatment of high speed and other alloy steels; discussion of various problems met in daily practice by heat treaters, shop foremen, steel salesmen, etc. Monday and Wednesday evening. First session, Monday, Feb. 6, 6:20 to 9:40 p. m. Tuition $20.00.

3E Metallurgy of Iron and Steel—A lecture course in descriptive metallurgy intended, primarily, for the nontechnical men in the iron and steel industry who desire to know the "why and wherefore" of the materials with which they work. A general study will be made of the blast furnace, bessemer, open hearth, electric furnace, puddling, and crucible processes. This should make it clear why one kind of steel is better than another for a given purpose. A survey will be made also of the operation of rolling mills, forge plants, and foundries. The last mentioned will include a brief study of cupola operation and molding-embracing the production of gray, white, and malleable cast irons. A study will be made of the various defects in steels and cast irons, including their causes, methods of detection, possibility of elimination, and their bearing on the physical properties of finished products. The entire subject will be viewed from the standpoint of the engineer and user of iron and steel. Monday and Wednesday evening. First session, Monday Feb. 6, 6:20 to 8 p. m. Tuition $10.00.

3D Metallography of Iron and Steel—A course in the preparation and microscopic examination of variously treated specimens of low and medium carbon steels, tool steel, high speed, and other alloy steels, wrought iron, and the various cast irons. Students prepare their own samples for examination employing the methods used in commercial laboratory practice. They make photomicrographs of many of their

specimens. A student satisfactorily completing this course should be able to interpret photomicrographs, and correctly diagnose a defective piece of steel. Lectures follow Sauveur's *Metallography of Iron and Steel*. Tuesday and Thursday evening. First session, Tuesday Feb. 7. 6:20 to 9:40 p. m. Tuition $20.00.

BUFFALO CHAPTER

The Buffalo Chapter held its regular January meeting on Jan. 17 at the Genesee hotel. Prof. D. W. Wilson of the Massachusetts Institute of Technology was to have presented a paper on the "Principle of Basic Open-Hearth Steel Making", but was unavoidably detained and could not be present, however the meeting was turned into a general discussion meeting led by Chairman Blocksidge and proved to be very interesting. A number of very important subjects were considered and discussed.

The February meeting will be addressed by President Gilligan and will be held on Wednesday, Feb. 15.

MILWAUKEE CHAPTER

On Tuesday, Jan. 24, at the Medford hotel, the Milwaukee Chapter held its regular monthly meeting. The speaker of the evening was National President Frank P. Gilligan, of the Henry Souther Engineering Co., Hartford, Conn., who presented a very interesting paper on "Material and Workmanship".

President Gilligan also presented various items of interest showing the activities of the National Society. His visit was thoroughly enjoyed.

PROVIDENCE CHAPTER

The January meeting of the Rhode Island Chapter Jan. 4 was addressed by Stanley P. Rockwell, metallurgical engineer on the subject of "Carburizing". The talk was illustrated.

Mr. Rockwell's experience as metallurgist with the New Departure Mfg. Co. and his further experience as consulting metallurgist, particularly qualified him to speak on this subject which included: carburizing materials; steels and their selection; impurities in steel affecting heat treatment; soft spots from carburizing, hardening, grinding and testing.

ROCHESTER CHAPTER

The Rochester Chapter held its January meeting on Wednesday, Jan. 11 at the Rochester Engineering Society rooms. The speaker of the evening was George Berry, chief chemist of the Halcomb Steel Co., Syracuse, N. Y., who selected as his subject "From Ore to Steel". His paper was illustrated and was of particular interest to all users of steel. A large number was in attendance.

DETROIT CHAPTER

The second December meeting of the Detroit Chapter was held at the Board of Commerce on Thursday, Dec. 29, and was addressed by Judge Pliney W. Marsh on "Things of Interest to Detroit Citizens". Judge Marsh had a thorough knowledge of the things that would interest Detroit citizens and his talk held the closest attention during its presentation.

The first January meeting was held on Monday, Jan. 9, at the Detroit Board of Commerce. The first meeting of the new year proved to be decidedly successful and a very interesting paper was presented by W. G. Calkins, metallurgist for the Detroit Twist Drill Co. Mr. Calkins' subject, "Forged High Speed Milling Cutters", was handled in

such a capable manner and proved so instructive to the tool men, designers, hardeners, and makers who were present that a considerable amount of discussion followed.

The second January meeting was held on Monday, Jan. 23, and was addressed by Henry Traphagan, consulting metallurgist of the Toledo Steel Castings Co., whose subject was "Fatigue of Steel". The notice of the meeting also contained the following note of interest to the membership:

"A class in elementary metallurgy will begin on Tuesday, Jan. 31, at Cass Technical high school, continuing every Tuesday evening from 7:30 to 9 o'clock, to consist of lectures and recitations, lasting until the middle of June. Register January 30 or 31 in the school annex, corner Second and High Street."

NEW YORK CHAPTER

The general meeting of the New York Chapter was held at the Engineering Society's building on Wednesday Jan. 18 at 8:00 p. m. Arthur W. F. Green, chief of the laboratory of the John Illingworth Steel Co., Philadelphia, presented an illustrated lecture on "The Annealing and Treating of Tool Steels." Mr. Green presented a very capable and instructive paper, and all those present were strong in their praises of the excellent manner in which Mr. Green had handled the subject.

The practical talks for the remainder of the season are as follows:

FEBRUARY:—Case hardening (carburizing and subsequent heat treatment) Ways of doing it, and what it does to a piece of steel.
MARCH:—Sectional Meeting, Friday, March 3.
APRIL:—Treatment of high speed steel.
MAY:—Hardening room troubles, shrinkage, warpage, scaling.
JUNE:—Spotting the reason for failures in service. Practical uses for microscopes and physical testing machines.
Added Attraction:—Current events, a 10-minute talk at each meeting on recently published items of interest to heat treaters. Come to the meetings and get into the discussions of the topic presented.

CLEVELAND CHAPTER

The Cleveland Chapter held its regular monthly meeting at the Cleveland Engineering Society's rooms, Hotel Winton, Friday evening, Jan. 27. The paper for this meeting was presented by W. R. Chapin, director of testing department of the E. C. Atkins & Co. of Indianapolis. The title of his paper was "Properties of Some Steels in the Hardening Range". Mr. Chapin is a very capable metallurgist and a very pleasing speaker and had a real message for the large number in attendance. Dinner was served at 6:30.

C. G. Shontz, chairman of the Cleveland Chapter, taught the January class in metallography in the Cleveland School of Technology of the Y. M. C. A. Mr. Shontz taught some classes on heat treating last semester and met with great success.

SPRINGFIELD CHAPTER

The Springfield Chapter held its regular January meeting on Friday, Jan. 27 at the auditorium of the Chamber of Commerce. The speaker of the evening was Walter F. Graham, metallurgist of the Henry Souther Engineering Co., Hartford, Conn. Mr. Graham's lecture was illustrated with lantern slides, and was presented on the following subject, "The Variation

in Hardness of Hardened Steel." The attendance was very satisfactory and all present enjoyed Mr. Graham's talk. Arrangements have been made for a visitation to the government arsenal, Saturday afternoon, Feb. 24.

NORTH WEST CHAPTER.

The regular meeting of the North West Chapter was held Wednesday evening, Jan. 18 at the Manufacturers' Club. Dinner was served as usual at 6:30, and the business meeting commenced at 7:30. The program committee was very fortunate in arranging an interesting evening. Three reels of motion pictures were exhibited. These pictures were produced by the Commonwealth Steel Company of St. Louis, Mo., and showed the methods of manufacturing open-hearth cast steel devices used in the construction of locomotives and cars. The pictures were explained by members of the Executive Committee who very gladly answered many questions that were asked at the close of the meeting.

SYRACUSE CHAPTER

The monthly meeting of the Syracuse Chapter was held on Jan. 6 in the auditorium of the Chamber of Commerce. Due to unforeseen circumstances, the regular speaker of the evening was unable to be present and consequently H. J. Stagg, chairman of the local chapter, substituted. Mr. Stagg's paper was unusual in that its scope was wide and he did not dwell too much on theory but quoted directly from experience with actual conditions. His fervid battle cry of "Heat slowly and uniformly, quench in suitable medium and draw immediately" will remain for some time with his hearers. About 100 attended the meeting.

INDIANAPOLIS CHAPTER

The January meeting was held on Jan. 10 at the Chamber of Commerce where a very interesting meeting took place. Moving pictures were shown. The question box was made a very important portion of the meeting and an elaborate discussion was participated in by the large number in attendance. W. R. Chapin, metallurgist E. C. Atkins & Co., will be the speaker at the chapter meeting on Feb. 6.

BOSTON CHAPTER

The Boston Chapter January meeting was held on Friday evening, Jan. 20. Stanley P. Rockwell, consulting metallurgist of Hartford, presented a very interesting paper upon the subject of "Carburizing". Mr. Rockwell was true to his previous reputation of being a first-class speaker and of having a fund of information upon this subject. The amount of discussion secured was very large and proved to be exceedingly profitable.

ST. LOUIS CHAPTER

The St. Louis Chapter held its regular meeting at the Engineer's Club at 8:00 p. m. on Friday, Jan. 20. The meeting was designated as a practical meeting, and was addressed by G. S. Rogers of the E. F. Houghton Co., on "Case Hardening," and C. B. Swander of the Wagner Electric Mfg. Co. on the subject of "Quick Tests." The meeting was very well attended and especially interesting. Quite a number of questions were presented and answered.

CHARLESTON CHAPTER

One of the best meetings the Charleston Chapter has had for some time was held on Thursday, Jan. 19, at the Kanawah Hotel. President Gilligan paid his first visit to the chapter and was greeted by a very

large attendance of members and their friends who enjoyed immensely the opportunity of meeting the National President. C. A. Gosztonyi presented an interesting paper on "Forging Practice" at the same meeting.

Lt. Col. A. E. White, past president of the National Society, will be the speaker at the meeting on March 7. His paper probably will be on the subject of "top discard" which will be of special interest to the United States Naval Ordnance Plant.

ROCKFORD CHAPTER

At a recent meeting of the Rockford, Ill., chapter, Otto F. Muehlemeyer, metallurgist of the Barber-Colman Co., Rockford, Ill., presented an exhaustive paper on the hardening of steel.

Commercial Items of Interest

FINAL arrangements have been made for holding the annual convention and exhibit of the American Foundrymen's Association and allied societies in Rochester, N. Y., during the week of June 5-9, instead of in Cleveland as announced previously. This decision, just announced by C. E. Hoyt, secretary of the association, was reached following conferences on Jan. 18 and 19 with Mayor Kohler, of Cleveland, at which time it was learned that due to the incomplete condition of the municipal auditorium, uncertainty as to when it would be open to the public, and the manner in which it would be operated, it would be impossible for the city to give a lease for any specific date in 1922. Because of these agreements, the present administration refused to honor the agreements which the previous administration had entered into with the Foundrymen's association.

Rochester previously had extended an invitation for this year's meeting and with the invitation promptly reaffirmed, that city was made the unanimous choice of the convention and exhibits committee and the board. All the activities of the association will be centered at Exposition Park, a million dollar show place located 1½ miles from the city. Comfortable and commodious assembly rooms for general and auxiliary meetings are available, while buildings No. 3, 4 and 5, all directly connected, afford better accommodations for all classes of exhibits than have been found in any city where exhibits have been held, it is understood.

Although it is known that the metalworking industry, because of the inherent hazards of its nature, has always been among the leaders in industrial safety, it has never been established definitely how many persons in the metalworking industry are engaged in accident prevention and industrial health work, or how this industry compares with other industries in this respect. All this will soon be shown when a census of safety men in the metalworking industry is completed. This census now being taken by the National Safety Council along with the census of safety men in all other industries and in public safety work.

This census will give a good indication of the extent of safety and health work in metalworking plants all over the country and will afford the first basis of comparison with the similar work being undertaken in other industries. This is the first time that any attempt has ever been made to list the thousands of people who are now professionally engaged in the safety movement. The census will include not only members and employes of members of the National Safety Council, but all persons engaged in safety and industrial health activities and not connected with the council at all. Many of the principal metalworking plants are members of the National Safety Council.

Every person professionally engaged in industrial or public accident prevention or industrial health work—whether he is devoting all or only

part of his time to accident prevention—is urged to assist in the taking of this census by sending to the National Safety Council,, 168 North Michigan avenue, Chicago, his name and the other data requested in the council's census form reproduced below.

It is expected that when the job of taking this census is completed there will be registered at the headquarters of the council the name of every man and woman responsible for the safety work of every industrial plant, public utility, municipality, and every organization which devotes any part of its efforts towards the promotion of either industrial or public safety, in the United States. Up to the present date no such data have been in existence.

Such a record will enable the council to find speakers on industrial and public safety for any occasion in any locality; authors for special articles on accident prevention; writers of safety textbooks; lecturers on accident prevention and industrial health work for universities and colleges. At present the council continually receives requests from industrial companies, municipalities, civic associations, clubs, schools, colleges, and other organizations for help in finding speakers or writers on safety subjects.

Following is the form which all safety workers are requested to fill in and send to the National Safety Council; 168 North Michigan avenue, Chicago:

Name .....
Company or organization .....
City ..... State .....
Nature of company's business .....
Is safety your principal work?
Please check other activities you engage in:

Fire protection	Legal
Health and sanitation	Insurance
Workmen's compensation and claims	Welfare
General executive (such as manager or superintendent)	Educational
Engineering (other than safety)	Industrial relations

How long have you been in your present position? .....
Technical or other special education? .....
Signed .....
Title .....

W. S. Rockwell Co., furnace engineers and contractors, 50 Church street, New York, announces that Gibbons Bros., Ltd., Dudley, Worcester, England, has been appointed as representatives of that company in the British Isles.

The Canton Forge & Axle Co. has acquired the drop forge plant of the Standard Parts Co., Canton, O. It is equipped with forging and heat treating devices, including drop hammers up to 12,000 pounds and upsetting machinery. Axles and other drop forgings for high-grade automobiles have been turned out. The new management will enter the market for commercial drop forge work in addition to the automotive work. This can be produced from the smallest to the largest heat treated alloy forgings ready for machining. The shop organization which has spe-

cialized on intricate heat treated alloy forgings, will remain unchanged under the new management. The company is capitalized at $300,000. Officers of the new company are: President, F. C. Moore; secretary, H. C. Holloway; general manager, Thomas F. Dupuy; chairman of the directors, F. A. Poor. Mr. Moore is president of the P. & M. Co., Chicago, manufacturer of railroad supplies. Mr. Holloway and Mr. Poor are also associated with the P. & M. Co.

Market of a multistage fan blower is the purpose of the increase from $15,000 to $60,000 in the capitalization of the Syracuse Industrial Gas Co., Syracuse, N. Y., manufacturer of heat treating equipment. The company does not expect to add any new equipment as the manufacture of its new product is to be carried on in the shop of W. C. Lipe, Syracuse, machinist.

The Surface Combustion Co., Inc., industrial furnace engineers and manufacturers, 366-368 Gerard Ave., New York, has been awarded the contract for an automatic heat treating furnace to be installed at the United States Naval Ordnance Plant, South Charleston, W. Va. This is a furnace for heat treating 16-inch armor piercing shells.

The Combustion Engineering Corp., New York, has opened a new branch office at 806 First National Bank building, Pittsburgh. This office will be in charge of W. C. Stripe, formerly manager of the Philadelphia office of the same company.

Among the recent specifications approved by the American Engineering Standards Committee, 29 West Thirty-ninth street, New York, were A 32-14, cold drawn bessemer steel automatic screw stock and A 54-15, cold-drawn open-hearth steel automatic screw stock. These specifications may be found in the 1921 volume of the American Society for Testing Materials Standards or copies may be obtained from the American Engineering Standards Committee for 25 cents each.

Five steel casting manufacturers who have co-operated in research work for a period of about 12 months now have constituted themselves into the Electric Steel Foundries Research Group. Major R. A. Bull has been selected to serve in the capacity of research director. The research headquarters of this group which heretofore have been at Sewickley, Pa., have been removed to the Spondly building, 639 Diversey Parkway, Chicago. The steel casting plants constituting this group include the Lebanon Steel Foundry, Lebanon, Pa., Ft. Pitt Steel Casting Co., McKeesport, Pa., Michigan Steel Castings Co., Detroit; Electric Steel Co., Chicago, and the Silver Steel Casting Co., Milwaukee.

According to a recent bulletin of the American Engineering Standards Committee, 29 West Thirty-ninth street, New York, the secretary of war has directed that supply branches of the army utilize in connection with their specifications the standards that have been or may be adopted by the American Engineering Standards Committee. This is part of a general policy of the war department to co-ordinate its whole

(*Continued on Page* 37)

EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

Important Notice.

In addressing answers to advertisements on these pages, a stamped envelope containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITIONS WANTED

FOREMAN OR ASSISTANT FOREMAN. Two years as hardener and two years as foreman of heat treating department, where employed at the present time. Has also had course in Metallography. Eastern location preferred. 1—11

CHEMIST & METALLURGIST. Ten years general experience in chemistry covering coal, oils, paints and varnishes, rubber, brasses, steels and cement. Five years experience in analysis, manufacture and heat treatment of tool and alloy steels. Was foreman in charge of electric furnace for 2 years. Location around Chicago preferred. Married. Salary desired $150.00. 1—12

HEAT TREATING FOREMAN. A man with six years experience in the hardening of tools, dies, etc., desires a position where he can use his knowledge to the best degree. Has worked in some of the largest plants in the country and can furnish the best of references. Address 1-5.

METALLURGICAL ENGINEER. Extensive experience with large firms and steel mills. Has served as metallurgist in large production steel mill, Age 27, Married. No preferences as to location. Willing to consider any position in the metallurgical department, annealing or heat treating departments providing there is an opportunity for advancement. Address 1-10.

METALLURGIST—With twelve years experience with automobile, locomotive, munitions and alloy steel manufacturers. Familiar with the manufacture, heat treatment and properties of all general iron and steel specifications, Open Hearth, Electric Furnace and Cupola practice. Age 30, married. Address 1-15.

SUPERINTENDENT OR FOREMAN—In heat treating department; 21 years experience in heat treating. Employed at present with large heat treating plant. Desire to make change. Salary desired $3000. Address 10-2.

TECHNICAL GRADUATE—As metallurgist or superintendent of heat treating department. Six years of extensive experience in chemical and physical testing and heat treatment of carbon and alloy steels in automobile and aeronautical motor plants. Best of references. Eastern location preferred. Salary desired $250 per month. Address 11-1.

FOREMAN OR INSTRUCTOR—Nine years instructor forge work, College Cornell University; four years foreman toolsmith and steel treater of large ship-building corporation. Thoroughly experienced in all classes of steel. Wages reasonable. Location preferred, Ohio, Massachusetts, New York, Pennsylvania, and Connecticut. 2-5

METALLURGIST—Chemist or Superintendent of Heat Treatment. Technical graduate. Extensive experience with some of the largest companies in the country, also steel mill experience. Heat treatment, tool hardening, annealing, pyrometry, chemical analysis, physical testing, metallography, magnet testing, tool testing, investigation of trouble and research. Age 26. Reasonable salary desired. Eastern location preferred. 2-15.

METALLURGIST—College graduate, at present metallurgist with prominent automotive concern, three years experience in general heat-treating, case hardening pyrometry, microscopic examination and chemical analysis. 2-10.

ASSISTANT—METALLURGIST—Technical graduate. Specialized on Pyrometer maintenance and installation. Five years experience in heat treating department and laboratory of several large automobile parts manufacturing companies. Experienced in handling of men. (Write for detailed experience.) Location preferred Cleveland. Salary desired $175.00. Address 2-25

METALLURGICAL ENGINEER—Columbia University graduate. 7 years experience in steel treating plant, also research department of large steel manufacturing company. Experience included laying out and overseeing commercial heat treatments of small automobile parts, and similar products, and testing of same; design and installation of heat treating equipment; installation and maintenance of pyrometers; research work on high tensile and shock resisting structural steels, tool steels, magnet steels, etc.; micro examinations and microphotography; magnetic measurements; critical temperature measurements. Salary $200—$250 per month, depending on location Address 10—3.

HEAT TREATING FOREMAN—Two years pyrometrical and heat treatment of gun forgings; one year heat treatment and physical testing of rolled bar stock, and simple analysis; 1½ years heat treatment, carburizing, and hardening of automobile forgings. Address 9 5.

FOREMAN: 30 years practical experience in heat treating, forging tool hardening, carbonizing. 5 years as foreman of heat treating. Location preferred in Pennsylvania, New Jersey, or Maryland. Salary desired $200 per month. Address 9-3.

CHEMIST OR HEAT TREATER—Technical graduate. Experience in chemical and physical testing, heat treating of steels, platinum metals and rare earths. Best of references. Reasonable salary. Address 12-10.

POSITIONS OPEN

STEEL SALESMAN—To travel in Pittsburgh territory—Selling experience and knowledge of heat treatment desired. Salary to begin $2700 to $3000. Address 2-20.

ANALYTICAL CHEMIST—Must be a correct and rapid worker thoroughly familiar with the analysis of ferrous and nonferrous metals. State in reply education, experience and salary desired. Address 2-22

SALESMAN WANTED—Living in Connecticut, to cover that territory on cutlery steels, tool steels, cold rolled strip, etc., for a company well known in the territory Prefer a man with practical knowledge of steel and some selling experience. Address 2-30.

(*Continued from Page* 35)

supply system with the best commercial practice, and to support a national program of engineering and industrial standardization. Colonel Wainwright, assistant secretary of war, is an enthusiastic supporter of such a program of standardization and congress recently provided that he shall be charged with the supervision of the procurement of all military supplies and other similar business of the department. All branches of the army are included in the order.

The Quigley Furnace Specialties Co., Inc., New York, is circulating a 4-page leaflet in which the use of a refractory material for making one-piece baffles is designed. The bulletin is well illustrated.

A forge shop and foundry for its water department is being built by the city of Philadelphia. A general contract for the work has been given to F. J. Ryan & Co., industrial engineers, Philadelphia. Equipment to be installed includes forges, billet heating furnaces, heat treating furnaces, core ovens, brass furnaces, lead furnaces, pumping and air pressure system and an oil-burning system for the heating boilers of the plant.

The Combustion Engineering Corp., New York has recently opened two branch offices. One is at 216 Latta Arcade, Charlotte, N. C., and the other is at Seattle, Wash., where the Fryer-Barker Co. will be the representative.

Effective Dec. 1, Nelson B. Gaskill of New Jersey became chairman of the Federal Trade Commission for a term of one year. Mr. Gaskill, who was vice chairman during the past year succeeds to the chairmanship under a rule which provides for rotation in the office among the several commissions. He was appointed to the commission in December, 1919 and entered upon duty in February, 1920. He served as assistant attorney general of New Jersey from 1906 to 1914. During the World War he served as a lieutenant colonel.

According to a recent announcement, the annual meeting of the Iron and Steel Institute will be held May 4 and 5, at the Institution of Civil Engineers, London. The annual dinner will be held on evening of May 4.

John F. Keller and S. A. Richardson, of the department of mechanical engineering, Lewis Institute, Chicago, announce that they are prepared to act in an advisory capacity in connection with heat treatment, case carburizing, and similar metallurgical problems and to accept a limited amount of laboratory work involving physical testing, determination of critical temperatures, preparation of photomicrographs and pertinent work.

A special resistor electric muffle furnace, which will stand a temperature up to 3600 degrees Fahr., is now being built for use in the department of chemical engineering, University of Wisconsin, Madison, Wis. This furnace with several others for melting purposes was de-

signed and constructed largely by students in the course of electric furnace practice. The heat treating furnace is unique in that it combines all of the advantages of a gas furnace with the higher temperature and temperature control possible in an electric furnace. It is fitted for investigation of refractory materials and heat treatment of metals over the highest temperature range. As it will operate continuously at or over 2000 degrees Fahr., with only 4 kilowatts at a cost of but 6 cents per hour or one-fifth as much as it costs to operate a gas furnace under similar conditions, the furnace offers exceptional economic qualities.

The Fitzgerald Forging & Heat Treating Co., Springfield, Mass., was organized recently and will operate a plant at 576 St. James avenue, in that city. M. V. Fitzgerald and Thomas J. Fitzgerald are partners.

For cleaning small metal parts, the Pangborn Corp., Hagerstown, Md., recently has developed a small sand blast which is portable and may be picked up and carried around. The hose machine consists of a suction type gun, with the blast action controlled by a trigger in the handle. Compressed air passing through the air jet creates a vacuum by which the abrasive material is brought from the hopper to the gun body, which forms a mixing chamber for the air and abrasive where it is given a swirling action, as produced by rifling of a gun barrel. This produces great effectiveness for the blast stream. Quickly interchangeable nozzles make possible its use in plants having the smallest volume of compressed air, or the least work. It operates at any pressure from as low as 5 to 100 pounds per square inch. A small cabinet is manufactured that can be set over the hopper of the hose sandblast and supplies an economical means of cleaning small parts, furnishing a complete self-contained continuous cabinet sandblast.

Oil burners and oil burning furnaces are described in 32-page bulletin published recently by the Denver Fire Clay Co., Denver, Col. The forepart of the booklet is devoted to a discussion of proper methods for burning fuel oil, a number of tables and charts being used. Several pages are devoted to illustrations of various types of furnace installations and burners. The booklet is profusely illustrated.

Chain Doors
on
Continuous Annealing Ovens
Stop chilling in cold weather.
The Strands of Chain covering openings do not interfere with entrance and exit of stock.
Write for Bulletin "H"
E. J. Codd Co., 700 S. Caroline St.
Baltimore, U. S. A.

ebruary

c fur-
abines
e and
or in-
over
at or
cents
under
ties.

Mass.,
s ave-
d are

stown,
d may
a suc-
handle.
which
body,
it is
is pro-
geable
me of
om as
ctured
ies an
e self-

ulletin
e fore-
burn-
pages
ns and

rs
vens
ering
h en-
he St.